Annex A Calculation of Ocean and Shore Activity

Estimating the amount of material deposited in the lagoon and onto JI is the goal. Dr. Leo Rahal (DTRA 2000a) modeled and predicted the deposition of plutonium from the explosion and fire from BLUEGILL PRIME and STARFISH using LE-1 as the center. The predicted plume covered areas of JI and the lagoon.

The first step is to take the BLUEGILL PRIME Deposition pattern (labeled Figure B-10 in DTRA 2000a) and reproduced here as Figure 19. (The units on Figure B-10 in the DTRA document are listed as ^{238}Pu, but that is a typographical error. It should be ^{239}Pu.)

The second step is to calculate the land area. The shoreline is estimated to be 100 yards from the launch site as the center of deposition pattern. The method is to take Figure 19 and enlarge it as Figure 20. The land area covered by the boundary of the Inner Line is broken into small geometrical units (squares, triangles, etc.) and then summed for the total area. The same approach is done for Middle Line and Outer Line areas. The calculations are shown in Table A-1.

Using the Inner Line, Middle Line, and Outer Line concentrations (μCi/m^2) for Figure 19 and multiplying by the land area (m^2), it is possible to estimate the amount of plutonium deposited on JI as 0.236 Ci. Those calculations are shown in Table A-1.

With the land activity calculated, the next step was to calculate the total activity released by BLUEGILL PRIME. Multiplying each concentration (Inner, Middle, and Outer) by its corresponding area gives the total activity. The calculation is shown in the bottom of Table A-1 as 1.66 Ci.

The ratio is easily calculated as 14% of BLUEGILL PRIME was deposited on JI and 86% into the lagoon area. These estimates are unclassified and are used to determine percentages.

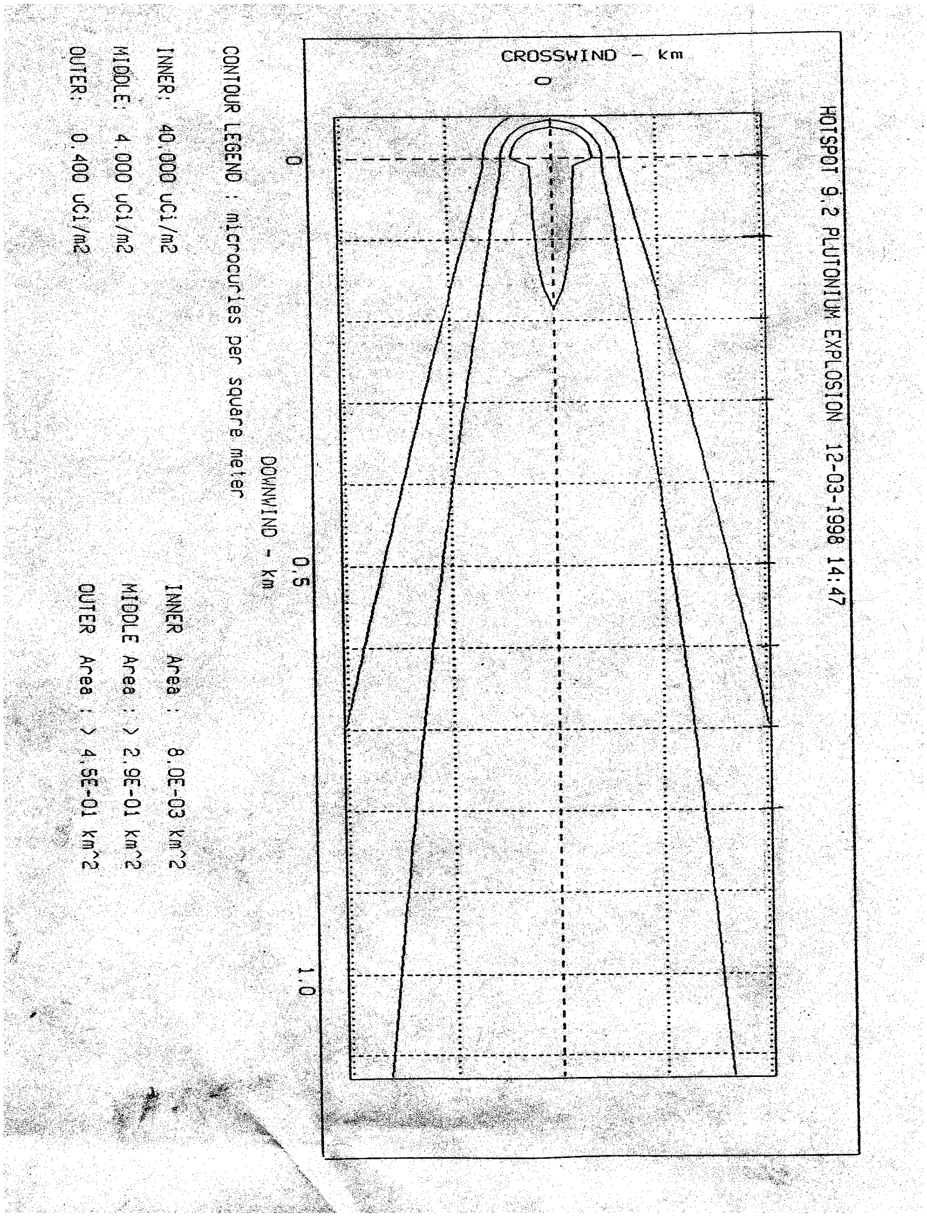


Figure 1 Estimated BLUEGILL PRIME Deposition Pattern

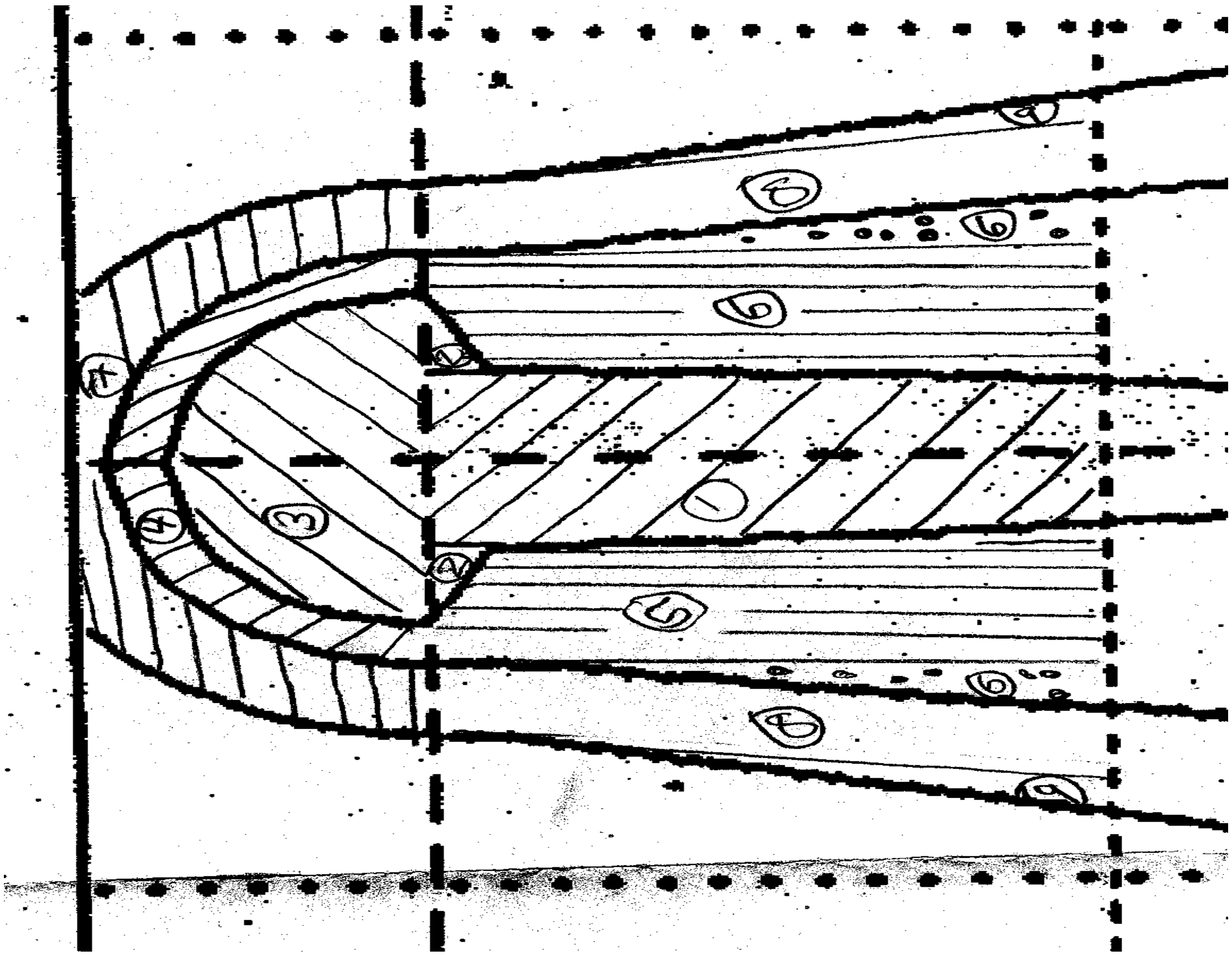


Table A-1 Calculation of Plutonium Percentage in Ocean and on JI from BLUEGILL PRIME

		Inner Line			Middle Line			Outer Line
Shape 1		Rectangle	Shape 4		Semi Circle	Shape 7		Semi Circle
	5.00E+00	wide at narrow end						
	6.00E+00	wide at wide end		7.00E+00	Outer Radius		9.00E+00	Outer Radius
	1.30E+01	Long		5.50E+00	Inner Radius		7.00E+00	Inner Radius
	7.80E+01	dots2		6.98E+00	Dots2		1.19E+01	Dots2
Shape 2		Two triangles on wings	Shape 5		Rectangle	Shape 8		Rectangle
	3.00E+00	wide		1.30E+01	Long		1.30E+01	long
	1.00E+00	high		7.00E+00	Wide		3.00E+00	Wide
	3.00E+00	dots2		1.82E+02	dots2		7.80E+01	dots2
Shape 3		Semi-Circle	Shape 6		Triangle (each side)	Shape 9		Triangle (each side)
	5.50E+00	Radius of circle		2.00E+00	Wide		1.00E+00	wide
	1.19E+01	dots2		1.30E+01	Long		1.30E+01	Long
				2.60E+01	Dots		1.30E+01	dots2
Conversion:	1.96E+02	dots2/10000m^2						
Total dots2	9.29E+01	dots2		2.15E+02	dots2		1.03E+02	dots2
Land Area	4.74E+03	m^2		1.10E+04	m^2		5.25E+03	m^2
Concentration	4.00E+01	μCi/m^2		4.00E+00	μCi/m^2		4.00E-01	μCi/m^2
Activity	1.90E+05	μCi		4.39E+04	μCi		2.10E+03	μCi
						Total Land Activity:	2.36E+05	μCi

<u>Predicted Total</u>			km^2	m^2	Total
Inner Line	4.00E+01	μCi/m^2	8.00E-03	8.00E+03	3.20E+05
Middle Line	4.00E+00	μCi/m^2	2.90E-01	2.90E+05	1.16E+06
Outer Line	4.00E-01	μCi/m^2	4.50E-01	4.50E+05	1.80E+05
				Total:	**1.66E+06** μCi of ^{239}Pu

The STARFISH event can be estimated in a similar manner at 88% into the ocean and 12% on JI using Figure 21.

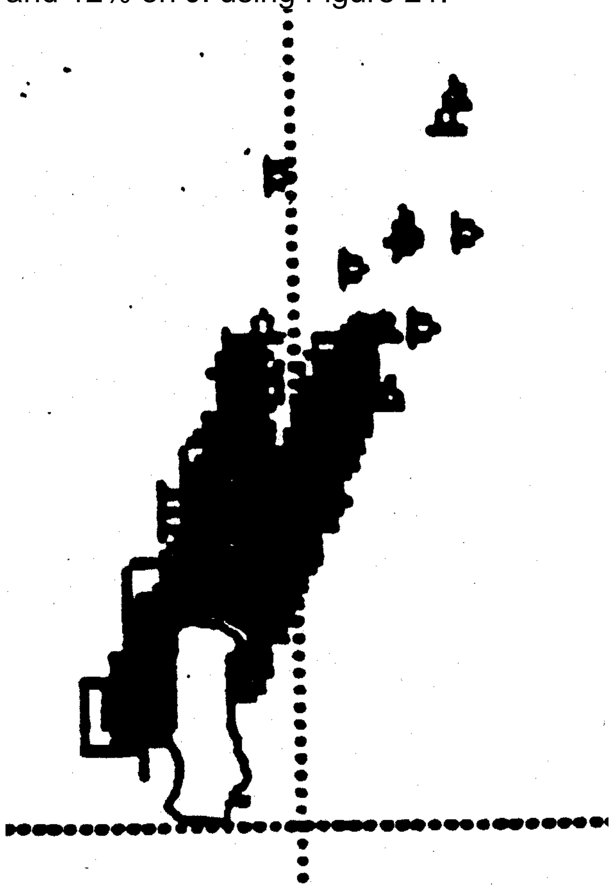


Figure 3 Estimated STARFISH Deposition Pattern over the Current Island Footprint

Now that the estimates for each deposition are completed, the next step is to take those estimates and multiply them by the amount of plutonium in the missiles. The International Atomic Energy Agency (IAEA) defines a "significant quantity" (SQ) as "The approximate quantity of nuclear material in respect of which, taking into account any conversion process involved, the possibility of manufacturing a nuclear explosive device cannot be excluded." For plutonium, a SQ is 8 kg.

For this mass and the projected deposition percentages into the ocean and lagoon, the activity deposited into the ocean and on JI can be estimated, as shown in Table A-2.

Table A-2 Estimated Summary of Activity into the Ocean and onto JI			
Significant Quantity	8 kg		
Specific Activity of ^{239}Pu	6.13E-02 Ci/g		
(PHS 1970)			
	Activity	Ocean	Land
BLUEGILL PRIME	490 Ci	86%	14%
STARFISH	490 Ci	88%	12%
	Estimated Totals	853.3 Ci	127.5 Ci

The estimated activity of the "above" pile with an average activity of 200 pCi/g is shown below in Table A-3.

Table A-3 Estimated Activity in "Above" Pile			
Average Activity	200 pCi/g		
		2.00E-10 Ci/g	
Estimated Volume of Pile	45,000 m^3		
		4.50E+10 cm^3	
Density	1.25 g/cm^3		
Total Pile Activity	11 Ci		

It is then possible to estimate the percentage of the "above" pile to the predicted activity in the lagoon. The calculation is 11 Ci/853.3 Ci or 1.2%.

Annex B JA Plutonium Ratios

JA plutonium oxides consist of five isotopes: ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, and ^{242}Pu. The plutonium in the environment at JA has a different isotopic mix than originally in the weapons because of radionuclide decay. There has also been substantial ingrowth of ^{241}Am (the decay product of ^{241}Pu), which emits a low energy photon suitable for measurement by direct gamma spectrometric methods. The chemical composition of the plutonium is most likely to be an oxide, as the bulk of the material released to the site surface was due to physical destruction of the warhead and subsequent burning on the launch pad. Plutonium metal is pyrophoric and burns/oxidizes rapidly when finely divided, such as after an explosion.

The isotopic mix used in derivation of cleanup levels for the JA RCA is shown in Table B-1. Because isotopic information is not available for the JA site, this distribution was derived from alternative non-classified sources. Specifically, data was obtained by the government laboratory responsible for the manufacture of the fissile components of the warhead. The isotopic composition of plutonium processes at the Rocky Flats Environmental Technology Site (RFETS) was age-decayed to provide the presumed present day isotopic composition of the weapons destroyed at JA (DOE 1996). ORNL, in conducting their research at JA, inferred a TRU-alpha activity by direct ratio to the measured ^{241}Am activity. In their work, a value of 6.51 was used (ORNL 1998). In comparison, the estimated 1999 activity presented in Table B-1 indicates a predicted ratio of TRU-alpha to ^{241}Am of 6.63. Table B-1 is taken from DTRA, 2000a. The 2% difference is negligible. Consequently, the method used to estimate the isotopic mix is reasonable.

Table B-1 Transuranics to Americium Ratio Calculations

(reproduced from DTRA 2000a)[a]

Nuclide & Principal Decay Mode	Half-Life, (years)	Initial Composition of RFETS Plutonium (% by Weight)	Initial Activity in RFETS Plutonium (Ci/g)[a]	Estimated Composition of Plutonium (% by Weight) 1999	Estimated Activity, 1999, (Ci/g)[b]
^{238}Pu (α)	8.77×10^{1}	0.01	1.7×10^{-3}	0.01	1.3×10^{-3}
^{239}Pu (α)	2.41×10^{4}	94	5.8×10^{-2}	94	5.8×10^{-2}
^{240}Pu (α)	6.53×10^{3}	5.8	1.3×10^{-2}	5.3	1.3×10^{-2}
^{241}Pu (β)	1.44×10^{1}	0.36	3.7×10^{-1}	0.09	8.7×10^{-2}
^{242}Pu (α)	3.76×10^{5}	0.03	1.2×10^{-6}	0.03	1.2×10^{-6}
^{241}Am (α)	4.32×10^{2}		7.5×10^{-3}	0.5	1.6×10^{-2}
			Initial Activity		**1999 Activity**
Specific Alpha Activity, Ci/g of Pu:			8.0×10^{-2}		9.0×10^{-2}
Total Specific Pu Activity, Ci/g of Pu:			4.5×10^{-1}		1.8×10^{-1}
Predicted Activity Ratio of:					
		$^{239/240}Pu/^{241}Am$:	9.47		4.44
		Pu Alpha/^{241}Am :	10.7		5.63
		Am + Pu Alpha Activity/^{241}Am	**11.7**		**6.63**
Total Pu /^{241}Am			60.0		11.3

[a]*Derived from data presented in "Action Levels for Radionuclides in Soils for the Rocky Flats Cleanup Agreement" corrected to 1999 time frame (DOE 1996).*
[b]*Based on the specific activity of plutonium unassociated with other materials.*

Annex C Conversion from Volume Activity to Area Concentration for Concrete

The density of coral (since concrete does not contain plutonium) is used with the 13.5 pCi/g concentration to determine the total activity in that volume (thickness of 1 millimeter). Then that activity is projected onto a two-dimensional surface.

$$Density\left({}^{g}\!/\!{}_{cm^3}\right) \times Concentration\left({}^{pCi}\!/\!{}_{g}\right) = ActivityperVolume\left({}^{pCi}\!/\!{}_{cm^3}\right)$$

Table C-1 Activity/gram to Activity/cm² Conversions

1.25 g/cm³	Density of coral
13.5 pCi/g	Project activity concentration
16.8 pCi/cm³	Using equation above
168 pCi/cm²	Projected volume onto a surface

The above calculations are for fixed contamination only. The unrestricted release standard, as stated in American National Standards Institute N13.12 (1987), is 20 disintegrations per minute/100cm² (dpm/100cm²)(removable) or 200 dpm/100 cm² total.

Annex D Metal and Concrete Cost Estimates

Cost estimates are based on DTRA engineering staff input, experience with contractor performance and contractor cost proposals.

D-1 Option 1: Scrap Metal Dealer and Island Riprap or Reef Building for the Concrete

This option requires 2 different tasks: radiological survey of the concrete debris and the movement of the clean concrete to its final location. The detailed breakdown of the cost is shown in Table D-1.

Table D-1 Estimated Costs for Concrete Option 1	
Subtask	Cost
Radiological Survey	$181,800
Dismantling of the Concrete	$74,000
Movement to Final Location	
Truck	$50,000
Barge	$80,000
Total Cost	**$385,800**

D-2 Option 2: Shipment to an Off-Island Radioactive Waste Facility

This option requires the radiological survey of the concrete to determine which pieces of concrete would require shipment offsite. The standard would be 168 pCi/cm^2 (fixed). The metal debris would be not surveyed since it is not cost effective or safe to survey by hand. The second task would be to dismantle the metal and concrete into sizes that would be small enough for placement in shipping containers. The third task would be to radiologically characterize the concrete and metal according to the final disposal site standards. The fourth task would be the shipping and disposal of the materials in a radioactive waste facility.

The amount shown for the concrete disposal is assuming the worst case (100% shipment). The summary cost table is shown below in Table D-2.

Table D-2 Estimated Costs for Metal and Concrete Option 2		
	Costs	
Subtask	Concrete Debris	Metal Debris
Survey Concrete	$181,800	
Dismantle the Piles and Equipment	$100,000	$900,000
Characterization	$100,000	$100,000
Placement of Piles in Shipping Containers	$200,000	$400,000
Transportation and Disposal	$0-395,500 (Dependent on the radiological survey results)	$4,500,000
Sub-Totals	$581,800-977,300	$5,900,000
Total Option Cost	$**6,481,800-6,877,300**	

D-3 Option 3: Landfill on JA

This option requires three tasks. The first is to dismantle the concrete and metal debris into manageable sizes. The second is movement of the concrete and metal debris into the LE-1 area for burial in place. The third task is the movement of covering coral. No assumptions are made at this time for the radioactive content of the covering coral. The estimated volume of coral to cover the debris piles at the stated design is 79,000 cubic meters. The estimated costs are shown in Table D-3.

Table D-3 Estimated Costs for Metal and Concrete Option 3		
	Costs	
Subtask	Concrete Debris	Metal Debris
Dismantle and Move the Debris	$100,000	$900,000
Move the Covering Coral Over the Debris	$420,000	
Sub-Total	$520,000	$1,320,000
Total Cost	$**1,420,000**	

Annex E Coral Attenuation Calculations

The attenuation of the americium gamma rays from the coral (calcium carbonate) is calculated according to Cember (1996).

The first step is to determine the chemical makeup of the shielding material ($CaC0_3$), the gamma energies of the isotope of concern (18, 30, and 60 keV for ^{241}Am), calculate the mass attenuation coefficient (MAC), and then the linear attenuation coefficient (LAC) for each element. The next step is to combine them all into the coral LAC. The linear attenuation coefficients allow attenuation calculations vs. coral depth for each gamma energy.

The equations, mathematics (Table E-1, 2, and 3) and resulting graph (Figure 22) are shown below for the 18, 30, and 60 keV gamma rays.

$MAC\ (from\ U.S.\ Department\ of\ Health\ Education\ and\ Welfare, 1970)$

Density ($element$), ρ (from Handbook of Radiaton Measurement and Protection, Brodsky)

Atomic Weights, A_w (from Handbook of Radiaton Measurement and Protection, Brodsky)

$$LAC(element) \equiv \frac{MAC(element)}{\rho(element)}$$

$$\text{Percent of Each Element in Coral Molecule} \equiv \%(element) = \frac{Each\ Element's\ Weight}{Total\ Coral\ Molecular\ Weight}$$

$$\text{Number of Atoms } {}^{1}\!/_{cm^3}\ (element\ in\ coral) \equiv N(element)$$

$$N(element) = \frac{6.02x10^{23}\ {}^{atoms}\!/_{mole}}{A_w\ (element)\ {}^{g}\!/_{mole}} \times \rho\ (coral)\ {}^{g}\!/_{cm^3} \times \%\ (element)$$

$$\text{Atomic Cross Section}(element) \equiv \frac{LAC(element)}{N(element)}$$

$$Coral\ LAC = \sum \left[Number(element\ in\ coral) \times \text{Atomic Cross section}(element) \right]$$

$$Radiation\ Intensity\ (with\ thickness\ x\ of\ coral) \equiv I_0 e^{-Coral\ LAC \cdot x}$$

Table E-1 Attenuation Calculations for the 18 keV Gamma Photon

Coral Chemical Formula is $CaCO_3$
For 18 keV gamma photon

	MAC	Density	Atomic Weight
	Cm^2/g	g/cm^3	
Ca	1.85E+01	1.55	40.08
C	5.57E-01	2.25	12.01
O	1.15E+00	1.14	15.99

Element	LAC	Number of Atoms/cm^3	Cross Section
Ca	2.86E+01	2.33E+22	1.22E-21
C	1.25E+00	1.12E+23	1.10E-23
O	1.31E+00	4.29E+22	3.05E-23

	% by Weight
Ca	4.01E-01
C	1.20E-01
O	4.79E-01
Sum	1

Density of Coral
1.25 g/cm^3

	Number of Atoms	Cross Section (cm^2)	Product	
Ca	7.53E+21	1.23E-21	9.25E+00	
C	7.53E+21	1.11E-23	8.36E-02	
O	2.26E+22	3.05E-23	6.89E-01	
		LAC	***1.00E+01***	cm^{-1}
		MAC	***8.02E+00***	cm^2/g

The graph showing the gamma attenuation versus coral depth is shown below for the 18 keV gamma (Figure 22).

Table E-2 Attenuation Calculations for the 33 keV Gamma Photon

Coral Chemical Formula is $CaCO_3$

For 33 keV gamma photon

	MAC	Density	Atomic Weight	
	cm^2/g	(g/cm^3)		
Ca	3.28E+00	1.55	40.08	
C	2.36E-01	2.25	12.01	
O	3.35E-01	1.14	15.99	

Element	LAC	Number of Atoms/cm^3	Cross Section
Ca	5.08E+00	2.33E+22	2.18E-22
C	5.31E-01	1.13E+23	4.70E-24
O	3.82E-01	4.30E+22	8.89E-24

	% by Weight
Ca	0.400507
C	0.1200237
O	0.4794693
Sum	1

Density of Coral
1.25 g/cm^3

	Number of Atoms	Cross Section (cm^2)	Product	
Ca	7.53E+21	2.18E-22	1.64E+00	
C	7.53E+21	4.70E-24	3.54E-02	
O	2.26E+22	8.89E-24	2.01E-01	
		LAC	***1.88E+00***	cm^{-1}
		MAC	***1.50E+00***	cm^2/g

The graph showing the gamma attenuation versus coral depth is shown below for the 30 keV gamma (Figure 22).

Table E-3 Attenuation Calculations for the 60 keV Gamma Photon

Coral Chemical Formula is $CaCO_3$
For 60 keV gamma photon

	MAC	Density	Atomic Weight
	cm^2/g	(g/cm^3)	
Ca	6.23E-01	1.55	40.08
C	1.75E-01	2.25	12.01
O	1.89E-01	1.14	15.99

Element	LAC	Number of Atoms/cm3	Cross Section
Ca	9.66E-01	2.33E+22	4.14E-23
C	3.94E-01	1.13E+23	3.49E-24
O	2.15E-01	4.30E+22	5.01E-24

	% by Weight
Ca	0.401
C	0.120
O	0.479
Sum	1

Density of Coral
1.25 g/cm3

	Number of Atoms	Cross Section (cm^2)	Product	
Ca	7.53E+21	4.14E-23	3.12E-01	
C	7.53E+21	3.49E-24	2.63E-02	
O	2.26E+22	5.01E-24	1.13E-01	
		LAC	***4.51E-01***	cm-1
		MAC	***3.61E-01***	cm2/g

The graph showing the gamma attenuation versus coral depth is shown below for the 60 keV gamma (Figure 22).

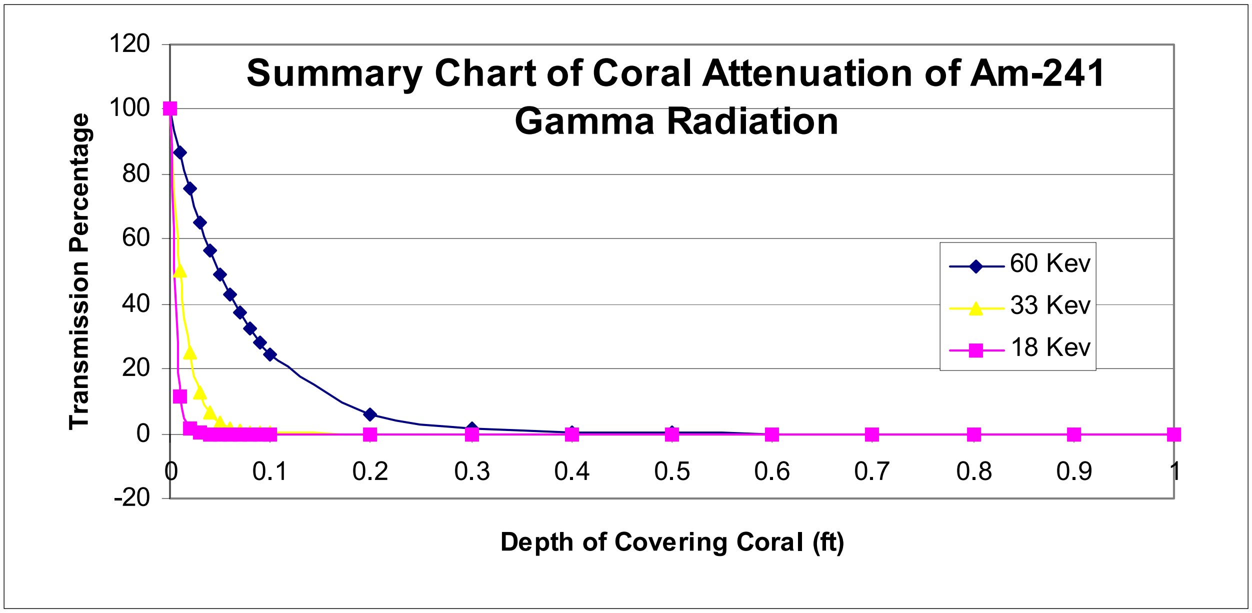


Figure 4 Gamma Attenuation of ^{241}Am: Transmission vs. Coral Depth

It is easy to see that radiological shielding does not mandate the coral cap thickness of 61 cm (2 ft). The coral cap thickness is based upon the expected burrowing depth of the birds.

Annex F "Above" Pile Cost Estimates

Cost estimates are based on estimates made by the DTRA engineering staff, experience with contractor performance and contractor cost proposals.

F-1 Option 1: Clean Cap

This option requires the same tasks as Option 3 for the metal and concrete debris. That cost estimate (Table D-3) serves as the base for the following cost estimates (Table F-1 to F-6).

Table F-1 Estimated Costs for Option 1 Clean Cap	
	Costs
Subtask	
Dismantle and Move the Debris	$1,000,000
Move the “Above” Coral Over the Debris	$420,000
Move the Covering Coral Over the Debris	$420,000
Total Cost	$**1,840,000**

F-2 Option 2: Clean Cap and Geotextile Liner

The option uses Option 1 as a basis and then adds to cost and installation of the liner (Table F-2).

Table F-2 Estimated Costs for Option 2 Geotextile Liner and Clean Cap	
Option 1 Cost	$1,840,000
Cost and Installation of Geotextile Liner	$60,000
Estimated Option Total	**$1,900,000**

F-3 Option 3: Clean Cap with Concrete Cap

The option uses Option 1 as a basis and then adds the concrete cap installation cost along with the cement transportation costs (Table F-3).

Table F-3 Estimated Costs for Option 3 Concrete Cap and Clean Cap	
Option 1 Cost	$1,840,000
Cost and Installation of Concrete Cap	$420,000
Barge Cost	$80,000
Estimated Option Total	$**2,340,000**

F-4 Option 4: Clean Cap over a 6-sided Concrete Vault

The option uses Option 1 as a basis and then adds the concrete vault design and construction costs along with the cement transportation costs (Table F-4).

Table F-4 Estimated Costs for Option 4 Concrete Vault and Clean Cap	
Option 1 Cost	$1,840,000
Cost and Installation of Concrete Vault	$1,230,000
Barge Cost	$80,000
Estimated Option Total	$**3,150,000**

F-5 Option 5: Clean Cap over a Concrete Slurry

The option uses Option 1 as a basis and then adds the concrete slurry construction costs along with the cement transportation costs (Table F-5).

Table F-5 Estimated Costs for Option 5 Slurry Mix and Clean Cap	
Option 1 Cost	$1,840,000
Concrete Construction Cost	$1,566,000
Barge Cost	$80,000
Estimated Option Total	$**3,486,000**

F-6 Option 6: Clean Cap Covering a Vitrified "Above" Pile

The option uses Option 1 as a basis and then adds the vitrification capital and operation costs (Table F-6).

Table F-6 Estimated Costs for Option 6 Vitrifying the "Above" Pile and Clean Cap		
Option 1 Cost		$1,840,000
Vitrification Costs	Description	
Plant Acquisition Cost	12,000,000 per plant	$12,000,000
Operating Cost	$80-165/ton with 45,000 tons	$3,600,000-7,425,000
Maintenance Costs	400,000 per year	$800,000
Labor Cost	(Based on a 4 person crew operating 24 hours a day, 7 days a week with a throughput of 100 tons per day for 45,000 tons)	$2,430,000
Barge Cost		$80,000
Estimated Option Total		$**20,750,000-24,575,000**

F-7 Option 8: Shipment of Entire "Above" Pile

The costs include characterization, transportation and disposal (Table F-7).

Table F-7 Estimated Costs for Option 8 Shipment of Entire "Above" Pile Off-Island	
Subtask	
Metal and Concrete Debris Landfill cost	$142,000
Characterization of "Above" Pile for Shipment	$300,000
Transportation and Disposal for "Above" Pile (45,000 m^3 at $1,100/$m^3$	$49,500,000
Total Option Cost	$**49,942,000**

Annex G GROUNDWATER SURVEY

G-1 Introduction

This document summarizes the results of a groundwater investigation performed to verify whether plutonium has been mobilized significantly by groundwater at the JA Plutonium Cleanup Project.

A characterization of the plutonium oxide by Argonne National Laboratory indicates the plutonium and americium contamination of JA coral soil is primarily in the form of scattered particles. The majority of the activity (>99%) was associated with particles ranging from 43 to 0.4 μm in diameter. The study suggests that a possible mechanism for dispersal is complexation with calcium carbonate (the main constituent of coral sand), followed by adsorption onto the coral soil. This would lead to a greater dispersal of plutonium and americium than would be expected by physical transport of discrete particles alone (Wolf et al. 1995).

The contamination at JA is from TRU elements (elements of the actinide series including plutonium isotopes and ^{241}Am) from failed missile launches during the 1960s. ^{241}Am is the daughter product of ^{241}Pu, which has a 14.35-year half-life. The primary types of radiation associated with TRU are alpha radiation, characteristic x rays from ^{239}Pu, and 60-keV gamma radiation from ^{241}Am.

Because the TRU contamination at JA exists in a highly oxidized form, it is especially likely to be immobile in all media. This assumption was tested in the technical approach herein, which included three scenarios to detect TRU in water: (1) leaching tests in columns, (2) well installation and sampling immediately downgradient of the source, and (3) existing well sampling.

The primary area of investigation was around the RCA on JI, the largest of the islands comprising JA that contains a pile of remediated coral (“below” pile) that consists of approximately 120,000 metric tons and an area of residual radioactive material (“above” pile) of approximately 45,000 metric tons. The remediated coral is generally on the eastern side of the RCA. The residual radioactive material is on the western side of the RCA, next to a former missile launch pad (LE-1) (Figure 23).

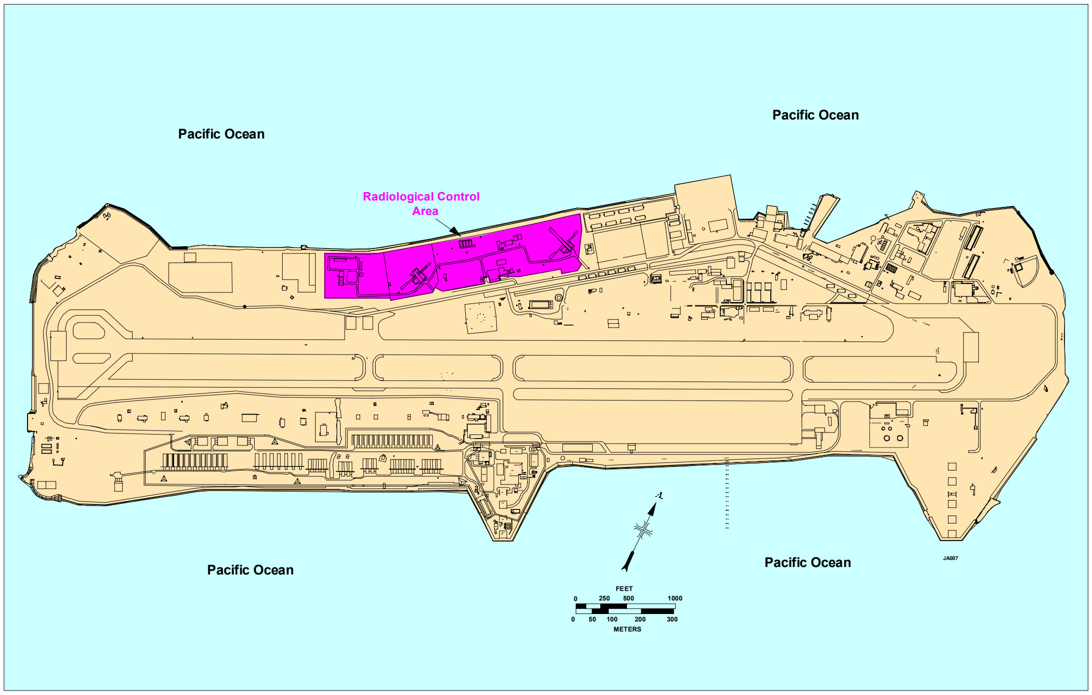


Figure 5 JI Map Showing the RCA.

Previous contractors have stated that the PuO_2 contaminant is relatively immobile in groundwater. However, recent studies of plutonium migration at other sites have given rise to the concern of plutonium transport at JI (EPA 1999a, Wolf et al. 1995).

The objective of this investigation was to provide independent data to determine whether plutonium migration is occurring at the JI site.

The groundwater investigation was conducted from May 17 to 31, 2000, and included field leachate testing, installing temporary monitoring wells along the shoreline between the RCA and the lagoon, and sampling existing monitoring wells at JI. Samples were analyzed for total TRU activity with radiochemistry in June and July 2000.

G-2 Contaminants of Concern

Contamination from the failed missile launches is from insoluble TRU present as dispersed activity (volume) and hot particles (point sources) (DNA 1991). The dispersed activity, particles approximately 10 μm in diameter with approximately 10 Bq of TRU activity, may be mobile within coral and could migrate due to precipitation runoff, tidal action, or in groundwater. The discrete hot particles, <45 μm in diameter and with activity >1,000 Bq, are relatively immobile unless affected by erosion, excavation, or physical means of disturbance (DNA 1991).

G-3 Applicable Guidelines

There are no site-specific guidelines for TRU in groundwater. The EPA has set a standard for radionuclides in drinking water of 15 pCi/L gross alpha for all alpha-emitting radionuclides, excluding radon and uranium (40 CFR, Part 141). Although the groundwater at JI is not considered drinking water, nor is it potable, this standard is used as a comparative measure in this report.

G-4 Environmental Setting—Groundwater at JI

A thin lens of brackish water underlying the original part of JI is encountered at depths of 1.2- 2.7 m (4 to 9 ft). Because of the high permeability of the soil and relatively low precipitation, there are no natural bodies of fresh water (DNA 1994). The hydraulic conductivity at the site ranges between 2.4 ft/d and 240 ft/d. The typical gradient toward the ocean is 0.001 ft/ft. Within the capture zone of the reverse osmosis (RO) unit wells, the gradient is 0.008 ft/ft.

The groundwater beneath the RCA is not a drinking water source. The source of potable water on JI is from groundwater supplied by upgradient wells and processed through an RO system housed in the Water Treatment Plant (Building 45). Examination of the island’s potentiometric surface shows the RCA to be cross-gradient to the RO wells. Therefore, the RCA is not in the RO capture zone.

G-5 Leachate Testing Experimental Methods

A leachate column experiment designed to simulate natural conditions at JI was performed using contaminated and uncontaminated coral from the RCA. Clean material was also collected from an area south of the RCA for use in the test. Each column was filled with uncontaminated, crushed coral, representative of the sediment found at JI. As the columns were filled, a plutonium spike (approximately 1/5 the volume of the respective columns) was added to the center of the column. The material in the columns was manually compacted to represent natural conditions as closely as possible. A Field Instrument for the Detection of Low-Energy Radiation (FIDLER) detector was used to isolate particles from an area of residual radioactive material to prepare the spike material. Gamma count rates from the particles were integrated over 3-minute periods and are summarized in Table G-1. The purpose of gamma screening was to ensure that radioactive material was present in the soil columns. The actual activity of the material was determined after conducting the experiment and is shown in ORNL, 2000. It should be noted that one of the particles in Column 1 is a magnitude higher than any of the other particles used in the experiment.

Table G-1 Gamma Exposure Rates of Isolated Particles	
Particles	cpm [a]
Column 1	
1	55,808
2	64,607
3	27,338
4	23,048
5	20,632
6	19,987
7	17,847
Column 2	
8	185,260
9	20,860
[a]Counts taken in 3-min intervals.	

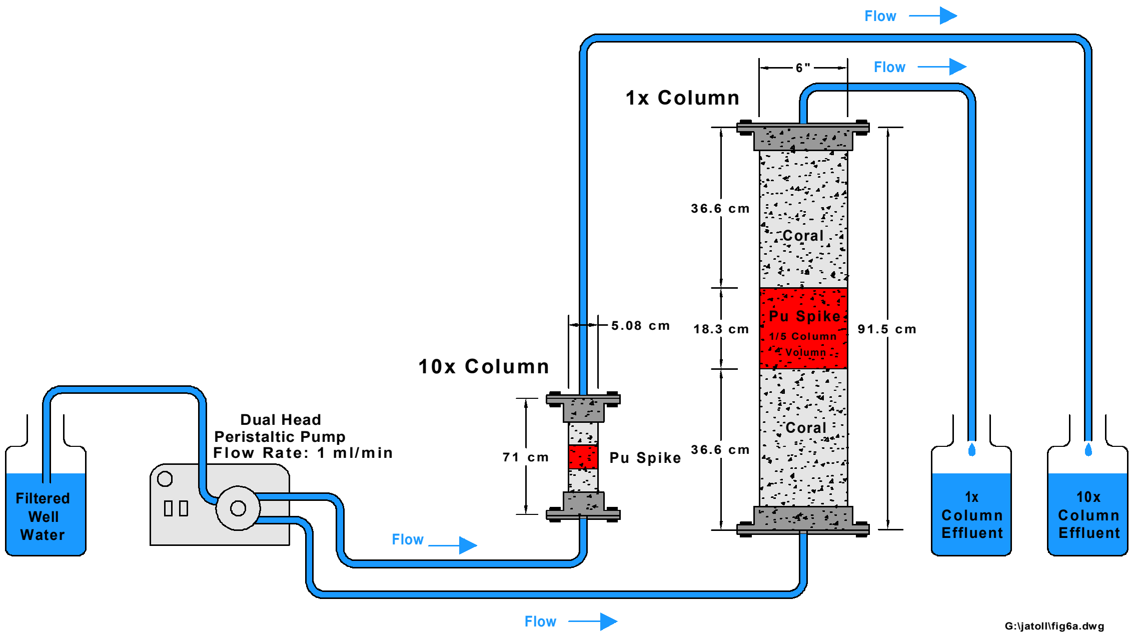
The extraction fluid used for leachate testing simulated the JI groundwater and was collected from a nearby existing well (SWMW09). Twelve gallons of water were collected for the test after purging 3 gallons. The groundwater extraction fluid was filtered using a 0.2-μm membrane filter. The filter and an aliquot of the filtered water were collected and submitted for analysis.

Because it is impossible in the leaching test to mimic natural conditions of velocity and gradient, the experiment used the lowest flow rate possible that could be regulated with certainty. This is considered an experimental limitation. To evaluate the possibility of colloidal transport, samples were analyzed in both filtered and unfiltered conditions.

Two columns were used in the leachate testing experiment (Figure 24 and 25). The first column was designed to simulate actual groundwater velocities as closely as possible. The second column was designed to be 1/10 the size of the first column and represents groundwater velocities 10 times natural conditions.

Johnston Atoll

SCHEMATIC OF LEACHATE COLUMN EXPERIMENT



Not to Scale
Conceptual Only

Figure 6 General Schematic Diagram of the Leachate Column Experiment

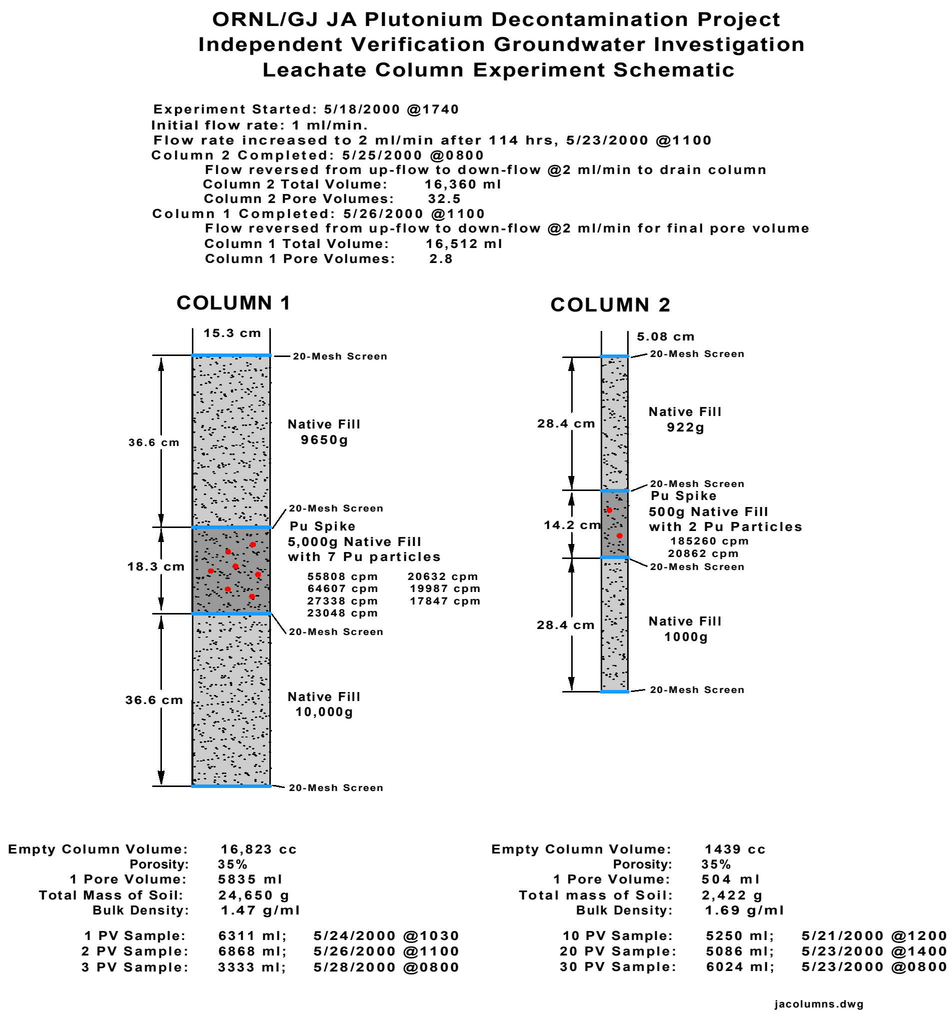


Figure 7 Detailed Diagram and Parameters of the Leachate Column Experiment

The large column was designed to be 3-ft long with a 6-in diameter (approximately 1,017 in^3) by assuming a flow rate of approximately 1 mL/min, a natural groundwater velocity of 1 ft/d, and a porosity of 0.35. Ten kg of clean material were placed in the large column. Next, a “20” mesh screen was placed below and above 5 kg of contaminated material to mark the position of the spike in the column. Finally, 9.65 kg of clean material was placed on top of the spike (Figure 25).

The dimensions for the smaller 10× column were 28-in long with a 2-in diameter (approximately 90 in^3). Again, a spike of contaminated material (500 g), marked by “20” mesh screen, was placed between two volumes of clean material (both approximately 1000 g) (Figure 25).

The resulting bulk density of column material (1.47 g/mL in the large column and 1.69 g/mL in the small column) was less than that found in natural conditions. This experimental limitation contributes a measure of conservatism to the test. The groundwater used as the extraction fluid for the test had a conductivity of 25.2 mS. The filtered water was pumped through the columns at a rate of 2 mL/min using a dual-head peristaltic pump. The column effluent was collected from each pore volume from the columns (ten pore volumes for the 10× column). Pore-volume effluents were collected in separate containers. One unfiltered composite water sample was taken from each of the containers. The remaining water was filtered using a 0.2-μm membrane filter. All groundwater and filter samples from the leachate test were scanned with a FIDLER (with no detection) before shipment. The filters and filtered and unfiltered water samples were submitted for TRU analysis by the described methods. After column testing was complete, the spike material was removed from the columns and was analyzed for TRU using DTRA's on-site gamma spectrometry. Results are presented in ORNL, 2000.

G-6 Methods of Installation and Sampling of Temporary Groundwater-Monitoring Wells

Field measurements of groundwater were collected at the RCA site to provide a quantitative measure of TRU concentrations within the groundwater immediately downgradient of the site and of the interface with ocean water.

Six temporary well locations (TW01 through TW06) were installed (Figure 26). The wells were located approximately 27 m (290 ft) apart, covering the shoreline area downgradient of the RCA in equidistant segments. The wells were located by using a Global Positioning System (GPS).

The well locations and their surrounding areas were scanned for the presence of TRU with a FIDLER before placement. No gamma measurements were detected above the background range of 1200 to 2300 counts per minute (cpm). Furthermore, all groundwater and filter samples were scanned with a FIDLER before shipment with no detection. The wells were installed using a 4-in. solid-stem auger; they were drilled to a depth of approximately 3.5 m (11.5 ft). The augers were removed and 5-ft sections of 3/4-in.-inside-diameter, flush-threaded, schedule 40 polyvinylchloride (PVC) casing and screen were installed.

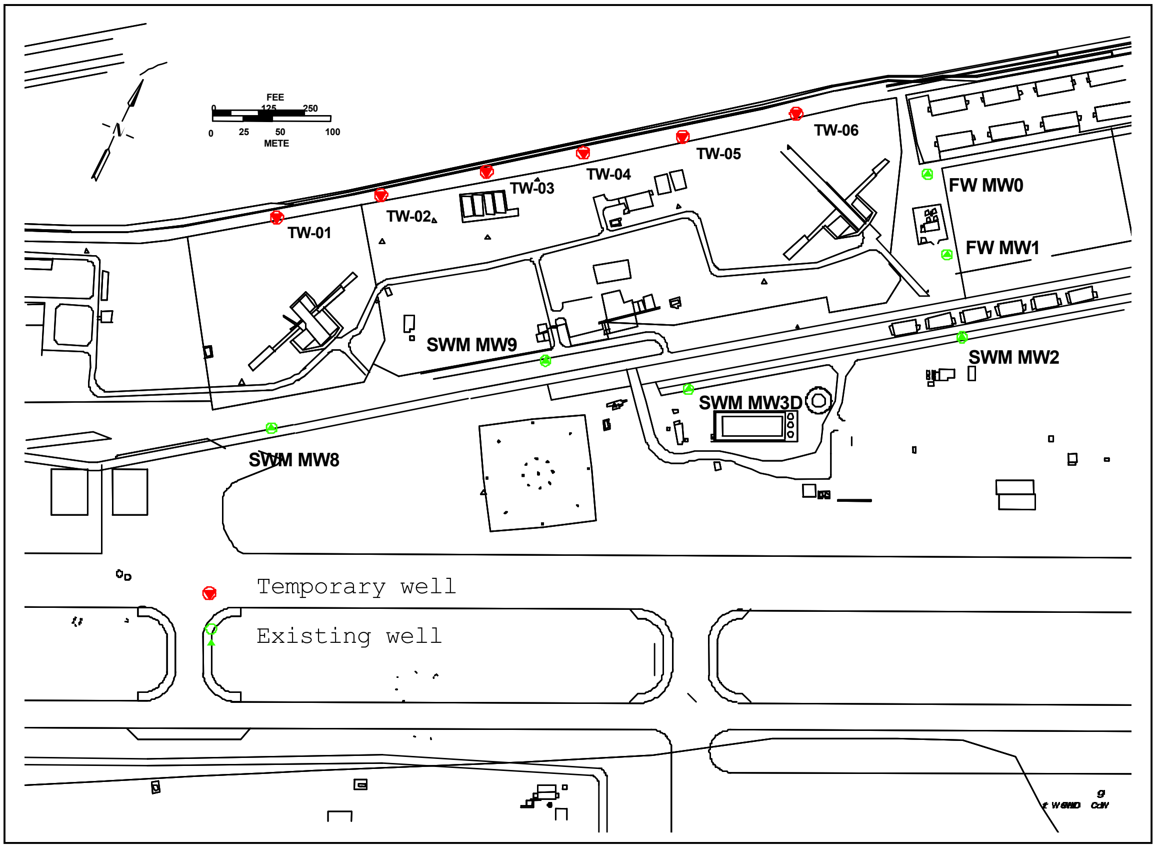


Figure 8 Locations of Permanent and Temporary Monitoring Wells

Most of the wells were installed to a depth of 3.2 m (10.5) ft. Drilling was difficult in some locations because larger coral cobbles exist at a depth of 1 m (3 to 4 ft) in the subsurface.

Field methods to install temporary monitoring wells and to sample groundwater were consistent with the general protocol defined in EPA 1992, EPA 1997, and ASTM D3370-82. The wells were installed using a Little Beaver manual driller. Soil cuttings were screened during installation for low-energy gamma rays associated with TRU contamination with a FIDLER. No elevated gamma ray count rates were detected. The temporary monitoring points were abandoned after sampling.

G-7 Methods of Sampling of Existing Groundwater-Monitoring Wells

Six existing groundwater-monitoring wells upgradient of the RCA were sampled for TRU (Figure 26). The wells were installed as part of the RCRA Facility Investigation in the early 1990s. The following existing wells were subject to sampling (Figure 26): FW MW 0, FW MW 1, SWM MW 2, SWM MW 3D, SWM MW 9, and SWM MW 8. It should be noted that the existing wells are all upgradient of the source (the RCA). However, they represent groundwater moving through the island and could have been subject to contamination from the events previously described.

The sampling of existing wells was consistent with the general protocol defined in EPA 1992, EPA 1997, and ASTM D3370-82.

G-8 Analytical Chemistry Methods

The water and filter samples from the leachate testing and well sampling were analyzed for TRU (^{241}Am, ^{244}Cm, ^{238}Pu, ^{239}Pu/^{240}Pu, and ^{242}Pu) as described below. The RC-19 RO6 procedure ("Determination of Americium, Curium, Plutonium, Neptunium, Thorium and Uranium in Water, Brine, Soil, Filters, and Organic Samples by Extraction Chromatography and Alpha Spectrometry") was used for analysis. This method was developed in large part by using articles by Horwitz et al. (1992, 1993 and 1995), who helped develop resins produced by Eichrom (Eichrom Industries method ACWO3 Rev. 1.4, "Americium, Plutonium and Uranium in Water"). To our knowledge, there is no EPA procedure for the separation of TRU.

Filtered and unfiltered water samples were collected in Nalgene bottles and were acidified with nitric acid in the field to a pH less than 2. There are no holding times or temperature requirements for the samples. Typically, 1.5 mL of 8-*M* nitric acid is added per liter of water to achieve a pH <2 and remain within the U.S. Department of Transportation (DOT) shipping regulations.

Aliquots of the samples were taken in the lab based on requested detection limits (1 pCi/L), interference in the sample, and/or approximate isotopic activities in the sample. Radioactive tracers are added to the samples (^{236}Pu for plutonium analysis and ^{243}Am for americium and curium analysis). Samples are stirred and oxidized to ensure that analytes and tracers are in the same oxidation states, and an iron hydroxide precipitation is done for the initial preconcentration.

This precipitate is dissolved in a nitrate solution for loading on Eichrom TEVA and TRU columns. Plutonium is fixed in the +4 oxidation state using ascorbic acid and sodium nitrite. The solution is loaded onto a TEVA column, which is stacked on top of a TRU column (the eluate from the TEVA column loads onto the TRU column). After rinsing the columns with additional nitrate solution, the columns are separated.

Purified plutonium is eluted from the TEVA column. Americium and curium are eluted from the TRU column. The purified isotopes are then precipitated from eluted solution using a cerium fluoride co-precipitation. The precipitate is then filtered from solution using a 0.1-μm polypropylene filter, which is mounted and counted by alpha spectrometry.

G-9 Gamma Scanning Methods

Gamma scans for health and safety and of drill cuttings were conducted using a FIDLER. Scan ranges in cpm were recorded in the sample logbook. Furthermore, all samples were scanned with the FIDLER. No readings were detected above the background range.

G-10 Quality Assurance/Quality Control (QA/QC) Methods

Table G-2 list types and numbers of field QC samples per sampling event set. The following QA/QC samples were taken or were included in the field-sampling effort. No trip blanks were taken because volatile organic compounds were not analyzed.

- Duplicate. One duplicate was analyzed every tenth sample. Results from duplicate samples were used to assess the precision of the sampling effort.
- Field blank. One field blank was collected per source per event. The field blank was prepared by collecting a sample of bottled water at the time of sampling. This bottled water was the same source as the water used in the final rinse during decontamination procedures. Deionized water was unavailable at the site.
- Equipment rinsate. One equipment rinsate was taken based on 10%/matrix per event. The equipment rinsate was taken by filling the decontaminated sampling equipment with deionized water and collecting a sample of the water.

Table G-2 Field QC for Groundwater Samples Per Sampling Event[a]

Type of sample	Number of samples
Lab duplicates	10%
Field blanks	One per event
Equipment rinsate	10%

[a]A sampling event is considered to be from the time the sampling personnel arrive at a site until these personnel leave for more than 24 hours.

Results of QA/QC are presented in ORNL, 2000.

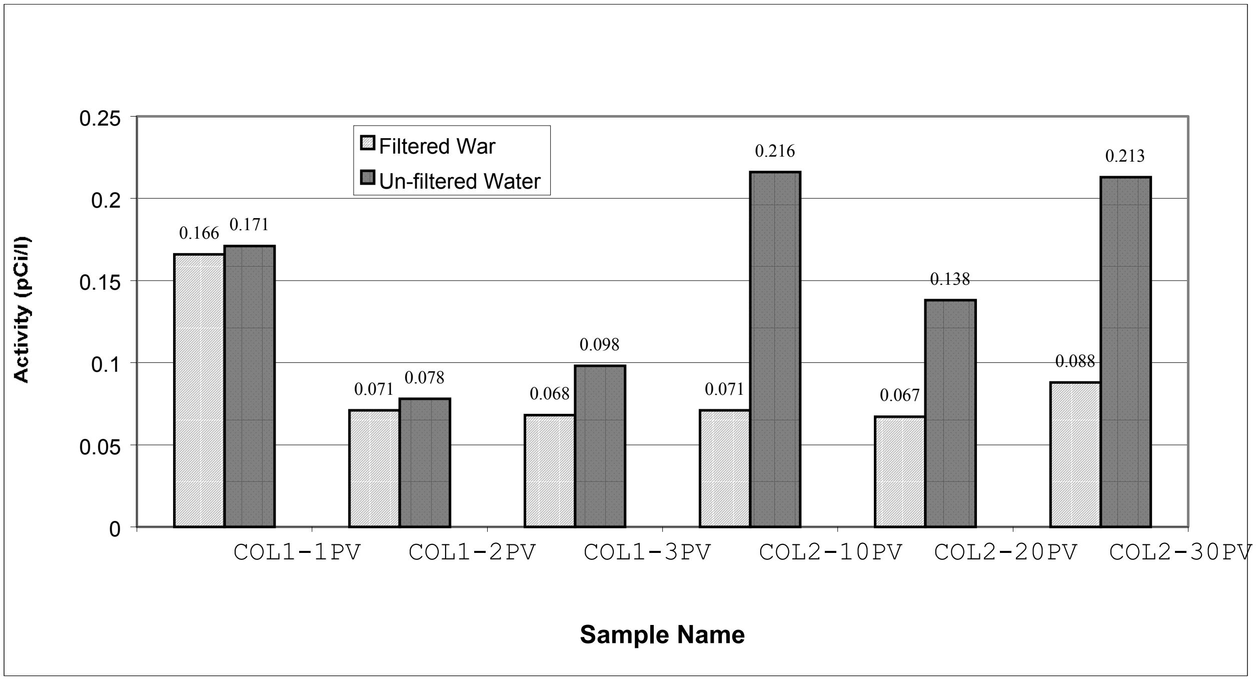


Figure 9 Graph of TRU Concentrations from JI Leachate Column Studies

G-11 Results

G-11.1 Leachate Testing Results

Total TRU in unfiltered groundwater from both columns ranged from 0.078 to 0.216 pCi/L (Figure 27). Total TRU concentrations in filtered samples of the same leachate ranged from 0.067 to 0.088 pCi/L (Figure 27). These results are far below the EPA drinking water standard of 15 pCi/L. Furthermore, most results were below the detection limits for TRU isotopes. Unfiltered groundwater leachate obviously contains particulates; however, TRU concentrations are negligible.

Specific activities in the spike material ranged as high as 13,750 pCi/g in Column 1 and 75,884 pCi/g in Column 2. It should be noted that specific activity in the native soils placed above and below the spiked material in the columns are comparable to background levels. If this material were to be considered mobile, these same high concentrations would be found in the unfiltered samples and associated filters.

G-11.2 Results of Sampling Temporary Wells

Figure 28 presents the results of sampling temporary wells (TWO1-TWO6). Samples were collected from depths where the conductivity was 52,800 or below (indicating the presence of brackish groundwater).

Total TRU concentrations in unfiltered groundwater from the temporary wells ranged from 0.047 to 0.181 pCi/L. Filtered samples had total TRU concentrations ranging from 0.03 to 0.072 pCi/L. Most isotopes were below the detection limits. The detections are miniscule in comparison to the 15-pCi/L guideline for drinking water.

G-11.3 Results of Sampling Existing Wells

Figure 28 presents the results of sampling existing wells (FW MW 0, FW MW 1, SWM MW 2, SWM MW 3D, SWM MW 9, and SWM MW 8). Total TRU concentrations in unfiltered groundwater from the temporary wells ranged from 0.039 to 0.16 pCi/L. Filtered samples had total TRU concentrations ranging from 0.01 to 0.059. Most isotopes were below the detection limits. The detections in water are miniscule in comparison to the 15 pCi/L guideline.

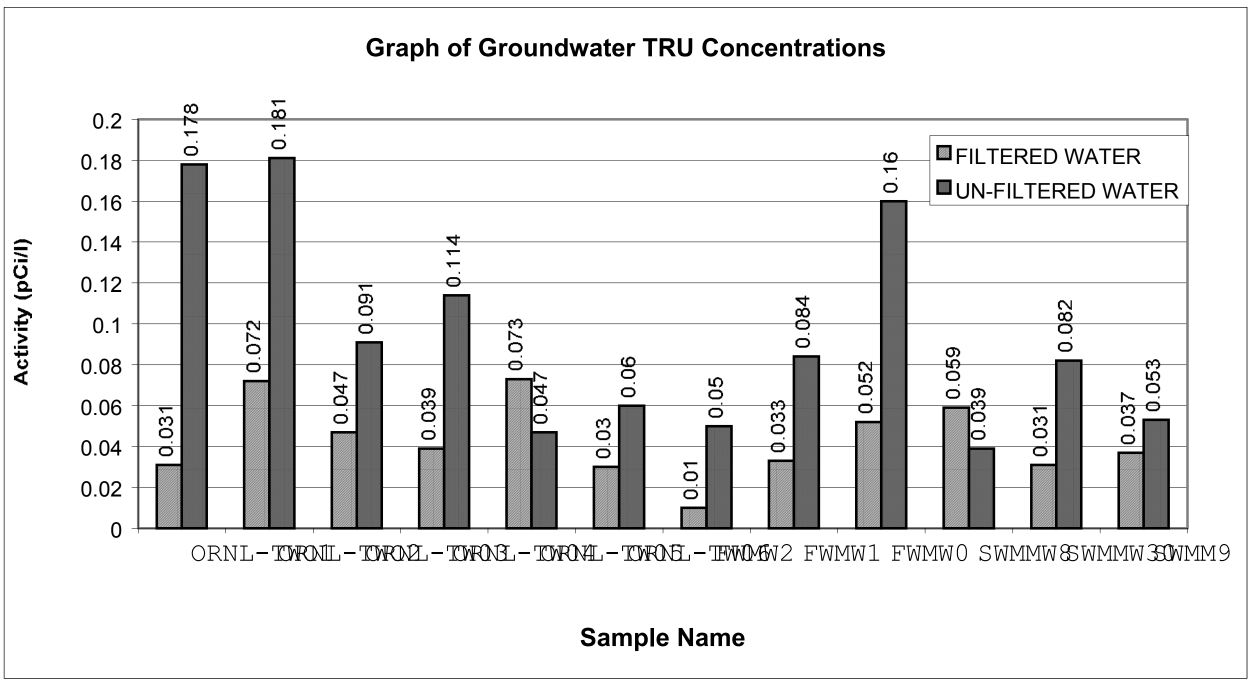


Figure 10 Graph of Groundwater Concentrations on JI

G-12 Discussion and Conclusions

The issue of TRU mobility in groundwater has been researched since the early 1970s. In general, TRUs, including plutonium, are relatively immobile in the environment (DOE 1980). Because the TRU contamination at JA consists in a highly oxidized form, it is especially likely to be immobile in all media. This assumption was tested in the technical approach herein, which included three scenarios to detect TRU in water: (1) existing well sampling, (2) well installation and sampling immediately downgradient of the source, and (3) leaching tests in columns. There were no significant detections of TRU isotopes in any of these waters. The highest concentration of total TRU isotopes in all 71 water samples was 0.181 pCi/L. This value is miniscule (1.2%) in comparison to the total alpha guideline in drinking water of 15 pCi/L. Furthermore, 180 out of 236 isotopic results were less than the minimum detectable activity (MDA). Finally, the conservative measures involved in the column testing favored the leaching or particulate movement of the spike consisting of elevated TRU material. However, no significant levels of TRU were found in the leachate or in the associated filters.

In regard to plutonium mobility, technical literature demonstrates that plutonium would not be mobile in the dissolved phase at JI. Hydrolyzable transuranic elements, such as plutonium, can only be maintained in solution by highly acidic solutions. Since coral sand is essentially pure calcium carbonate, acidic solutions are not possible in equilibrium with the soil. Thus, the particulate plutonium that is present at JI is not soluble when leached by rainwater or seawater. Even if plutonium were dissolved in an acid solution, once contacted with soil and diluted, the plutonium will be rapidly immobilized as a result of hydrolysis and subsequent precipitation on particle surfaces (Wildung and Garland 1980).

Numerous studies have also demonstrated that natural systems do not promote the mobility of plutonium. For example, freshwater studies have concurred that sediments appear to be the major reservoir for plutonium deposition. These studies concluded that even with contaminated sediments, transport of plutonium through biotic systems to man is insignificant (Emery and Klopfer 1976, Hakonson et al. 1976).

A study using soil from Nevada is also relevant, although it involved a nonmarine soil. The soil was calcareous (high in calcium carbonate) as is the soil (crushed coral) at JA. In this research, the authors attempted to leach plutonium from the soil by using HCl and NaOH to vary the pH of the extraction solution (Nishita and Hamilton 1981). Although these experiments are not an exact analog to using seawater or rainwater, there are useful similarities, such as their high ionic strength and pH. In these experiments, less than 1% of the plutonium could be leached under alkaline conditions in the same pH range as seawater. These data indicate the strength of plutonium sorption by calcareous soils.

Also, a monitoring program conducted from 1993 to 1995 at the Rocky Flats Plant concluded that plutonium was largely immobile in semiarid soils. Only 1 to 3% of the plutonium was released when large rainfall simulators were used to simulate very heavy rain. The plutonium that was released during the simulated rainfall, however, was found almost exclusively on suspended particulates (Litaor et al. 1998).

In summary, the technical literature provides ample precedent, based both on field studies and on plutonium's geochemical properties, to state with confidence that plutonium will not dissolve in the environment prevalent at JA.

Furthermore, the column studies demonstrate that neither particulate nor dissolved plutonium mobilize readily in JI groundwater because no elevated TRU concentrations were found in filters or in the filtered and unfiltered water samples. Therefore, in consideration of these tests, the DTRA believe that the TRU contamination at JI can be considered essentially insoluble in groundwater at the site.

Annex H LAGOON SURVEY - Sediment Sampling of the JA Lagoon

H-1 Summary

Plutonium oxide concentrations both in surface and sub-surface sediments of the JA lagoon were characterized, and comparison data were established for biological sampling. There were a total of 197 laboratory samples prepared and analyzed from 113 sediment cores (109 usable) taken from the atoll; 37 offshore of the RCA, 11 surrounding Sand Island, and 61 scattered across the rest of the atoll. 5 out of 197 laboratory samples had plutonium oxide concentrations above the soil cleanup level of 13.5 pCi/g, but only one was on the surface (0-7.6 cm depth (0-3 in depth)) with its activity at 14.9 pCi/g. The results show that the highest concentrations are at sediment depths between 15-30 cm (6-12 in). All elevated readings were collected from the area offshore of the RCA, as expected.

The area around Sand Island was of concern as well, since the Historical Site Assessment (HSA) identified recovered debris from the STARFISH event in this area. No readings above the soil cleanup level were detected from the 19 laboratory samples prepared from core collection sites around the perimeter of Sand Island.

The lagoon survey results show that the existing plutonium oxide in the lagoon is concentrated in rare spots and is no longer at the surface. The present hazard to lagoon biota is therefore considered minimal.

H-2 Historical Site Assessment

H-2.1 Background

The HSA conducted as part of the Johnston Atoll Radiological Survey (DTRA 2000a) established the most likely areas of contamination. Of the four aborted tests, only two would have contributed to the dispersal of radionuclides in the lagoon. Most of the debris and residual plutonium from the STARFISH event landed on JI, adjacent Sand Island, and in the water surrounding them. The BLUEGILL PRIME event and ensuing fire and smoke from the launch area, scattered radioactive material primarily downwind of the launch emplacement due to the predominant winds from the east and northeast.

H-2.2 Contaminants of Concern

The HSA established that the residual contaminant was WGP which consists of five alpha-emitting TRU isotopes as previously described.

H-3 Objectives of the Survey

The objectives of the plutonium oxide characterization survey for the JA lagoon were twofold.

1) Sediment characterization of lagoon plutonium oxide concentrations both at the surface and sub-surface.

2) Provide comparison data for biological sampling.

H-4 Sample Collection

H-4.1 Introduction and Overview

The DTRA contracted with the USACOE for the collection of the sediment cores. The USACOE then subcontracted with Arthur D. Little, Inc. (ADL) and Environet, Inc., who performed core collection with a team comprised of three personnel. Cores were collected between 15-20 November 2000 with an additional two days of mobilization and demobilization. The team collected 113 sediment cores during the 6 days, with an average core length of approximately 38 cm (11 in). For a map detailing the sample locations, see Appendix F of DTRA report 2001b.

Core collection was accomplished using two different methods. Method 1 (Section H.4.2) was used for the first 3½ days after which Method 2 (Section H.4.3) was used exclusively. Method 1 was unable to consistently recover the desired core length of 46 cm (18 in) of sediment per the Sampling and Analysis Plan (SAP). After consultation with the USFWS Manager and the USACOE, Method 2 was approved and utilized. All but 4 of the 113 sediment cores recovered provided sufficient volume to meet the objectives of the survey (to characterize lagoon plutonium oxide concentrations at both the surface and sub-surface and provide comparison data for biological sampling), and had laboratory samples prepared. The four cores which did not have laboratory samples prepared were FIDLER scanned with no detects and archived. Cores collected from both methods penetrated the sediment surface until refusal or to a maximum depth of 61 cm (24 in).

Both methods utilized a Raytheon Raychart 320 Satellite Differential Global Positioning System (SD-GPS) which uses the Wide Area Augmentation System for a differential correction. GPS coordinates were recorded for each core location.

Cores were marked clearly with pre-printed labels that denoted the core top. Field notes were taken for each sediment core and compiled into a Field Database, (see Appendix A of DTRA report 2001b). A Chain of Custody Record documented each day’s collected cores as they were delivered from the collection team to the DTRA, which handled sample preparation and laboratory analysis.

H-4.2 Collection Method 1

The first method used a vessel equipped with a temporary davit and 12 volt electric winch for deploying and recovering the sample equipment. Sediment was collected with a modified Diedrich Drill split spoon sampler, deployed from the vessel.

Prior to each deployment, the core collection equipment was cleaned. The field team visually assessed the bottom topography from the vessel and avoided coral reefs by positioning the equipment over areas in the lagoon free of coral formations. The core unit was lowered on a cable guided by a scuba diver until it reached the bottom and the pneumatic vibratory motor was activated to allow the coring equipment to penetrate to a maximum depth of two feet or refusal. After retrieval of the equipment, the polycarbonate tube was removed from the coring equipment and covered with polyethylene caps on the top and bottom. Cores were stored upright on the vessel at ambient temperature conditions and kept in the shade.

H-4.3 Collection Method 2

A scuba diver using the 2-inch OD polycarbonate liner tube, collected each sediment core from an area free of coral formations. Each tube was manually pushed into the sediment until refusal or to a maximum depth of two feet. The top end was covered with a polyethylene cap to create a vacuum and the tube slowly withdrawn. When the bottom end of the collection tube was clear of the sediment surface, another cap was used to cover the bottom.

H-5 FIDLER Scanning

The purpose of scanning each core was to look for high activities before sample preparation and to detect isolated plutonium oxide particles that might be present.

H-5.1 Equipment

A single five-inch diameter Ludlum 2221 FIDLER was used to conduct the scanning. This instrument is designed expressly to detect the low energy gamma radiation emitted by ^{241}Am. A source and response check was conducted twice daily (before and after scanning) using a known ^{241}Am source for quality assurance. All quality assurance checks for each day of scanning were within the industry standard of 10% of the baseline limits and indicate the FIDLER functioned properly. The daily background level prior to scanning was established by averaging three, one-minute ambient air counts. For the FIDLER Source/Response Check results and the Daily FIDLER Background results, see Appendix B of DTRA report 2001b.

H-5.2 Scanning Procedure

All cores had excess water decanted into a centralized container prior to FIDLER scanning. This excess water was then scanned with the FIDLER and determined to be free of any radioactive material.

FIDLER scanning was conducted for all 113 cores over the entire length of the polycarbonate tube prior to extrusion. 10-second stationary readings were recorded in cpm for each core. The core length was the determining factor as to how many stationary readings were taken per core (DTRA report 2001b).

H-5.3 Scanning Results

FIDLER scanning results (DTRA Report 2001b, Appendix C) determined 2 out of 113 cores had readings greater than twice the background level. One core (station number 17) had an elevated reading in the bottom third. The other core (station number 32) contained two elevated readings, one at the top or surface and one in the middle. Because the FIDLER scan found an elevated reading in the middle section of the core, a sample was prepared and analyzed by the laboratory counting equipment. See Table H-1 for a summary of the results from these two cores.

Table H-1 Sediment Sampling Results for the Two High Cores

Station Number	Core Length (in)	Bkg (cpm)	FIDLER Scanning and Laboratory Results Determined by laboratory counting equipment		
			Bottom	**Middle**	**Top**
17	8.4	631	2795 cpm / 677.9 pCi/g		914 cpm / 14.9 pCi/g
32	21.6	638	676 cpm / 9.3 pCi/g	3002 cpm / 347.8 pCi/g	1743 cpm / 3.9 pCi/g

H-5.4 FIDLER Scanning Results and Sediment Sample Concentrations

Results from laboratory analysis of the five samples prepared from these two cores (station numbers 17 and 32) show three of the five samples were above the established soil cleanup level of 13.5 pCi/g. Both of these cores were collected offshore of the RCA. For a map of specific locations, see Appendix F of DTRA Report 2001b.

H-6 Sample Preparation for Laboratory Analysis

H-6.1 Introduction and Overview

DTRA prepared laboratory samples in accordance with guidance received from the EPA Region IX. Of the 113 sediment cores collected, 109 (four sediment cores did not provide sufficient volume to prepare a sample) were used to prepare 197 samples for analysis. Each sediment core was to have two laboratory samples prepared (109 cores X 2 = 218), one from the top three inches and one from the bottom three inches. However, all cores were not able to have a top and bottom sample prepared for laboratory analysis (N=197). One or more of three reasons apply:

1) not enough core volume was collected for laboratory analysis
2) only enough core collected for one sample to be prepared
3) a rock or piece of hard coral prevented laboratory analysis

H-6.2 Preparation Procedures

Cores were extruded from the top of the polycarbonate collection tube using a fitted plunger. Each core was pushed out to expose approximately the bottom three inches, cut and placed on an aluminum pie plate. The remaining core was pushed out of the collection tube, and the top three inches was cut and placed on a separate aluminum pie plate. One core (station number 32) as noted above, due to an elevated FIDLER scan reading, also had a middle aliquot prepared. Any remaining core was archived in a double-bagged plastic container.

Sample aliquots were dried in an oven at 400^{o} F for 6 hours and air-dried for 48 hours. Each sample was prepared as directed by EPA Region IX in accordance with paragraph 32.5.1 *Cone-and-Quarter Method,* as outlined in the American Society for Testing and

Materials (ASTM 1996) method E-300. Once coned and quartered, each sample was then put into a 100 milliliter (mL) centrifuge tube for laboratory analysis and weighed in grams. The sediment weight was recorded, along with the sample identification number on each centrifuge tube. Remaining sediment from this procedure was archived along with any of the remaining extruded core.

H-7 Laboratory Analysis

H-7.1 Instrumentation

The counting systems used for the sediment samples were custom designed by American Nuclear Systems (ANS). The laboratory analysis utilized four detector/counting chambers to do on-site quantitative gamma spectroscopy analysis. The systems count samples in 100 mL centrifuge tubes. A summary of the equipment used in the laboratory counting systems is provided below.

Gamma Spectroscopy MCA Counting System Description

MCA Detector	Pre-Amp Software Shield	Version	Materials
ANS, Quantum MCA	Harshaw NaI (TI) 5 x 8 inch well	Quantum MCA Gold/Pu, Ver. 2000R 3.71.26	Pre-World War II Steel with Pb and Cu lining

The four detectors are identical cylindrical NaI (TI) detectors connected to pre-amplifiers, which feed the detector signals to an ANS Quantum 2000R multi-channel analyzer (MCA). The MCAs for all four systems are connected to a single desktop computer for analyzing the spectral data. The computer used the ANS Quantum MCA Gold/Pu, version 3.71.26 analysis software. The centrifuge tube containing the sample was inserted into the central detector well. The sample is almost totally surrounded by the NaI (TI) detector, which yields a high counting efficiency.

Standards and Procedures - The laboratory had a specially designed and calibrated, National Institute of Standards and Technology traceable ^{241}Am source for calibrating each of the systems. Each source was contained in a centrifuge tube. Each unit was calibrated and used per a standard operating procedure, see DTRA report 2001b.

Instrument Sensitivities and Efficiency – The laboratory counting system efficiencies are listed in the DTRA report 2001b.

Data Recording - The computer software automatically performed data recording. Data obtained from background and sample counting was retained as a hard copy in a specially designed spreadsheet. Appendix D of the DTRA report 2001b has a complete list of the data.

H-7.2 QA/QC Procedures

Forty-eight of the 197 samples (24%) were randomly selected for recount to provide quality control and assurance. Additionally, there were five samples above the soil cleanup level of 13.5 pCi/g. They were included in the 48 recounts to ensure accuracy.

The QA/QC data results shown in Appendix E of the DTRA Report 2001b, confirm that the counting system performed to standard and the counting results are valid.

H-8 Sampling Results and Conclusions

A complete list of the raw laboratory results is in Appendix D of the DTRA Report 2001b.

H-8.1 Offshore RCA Results

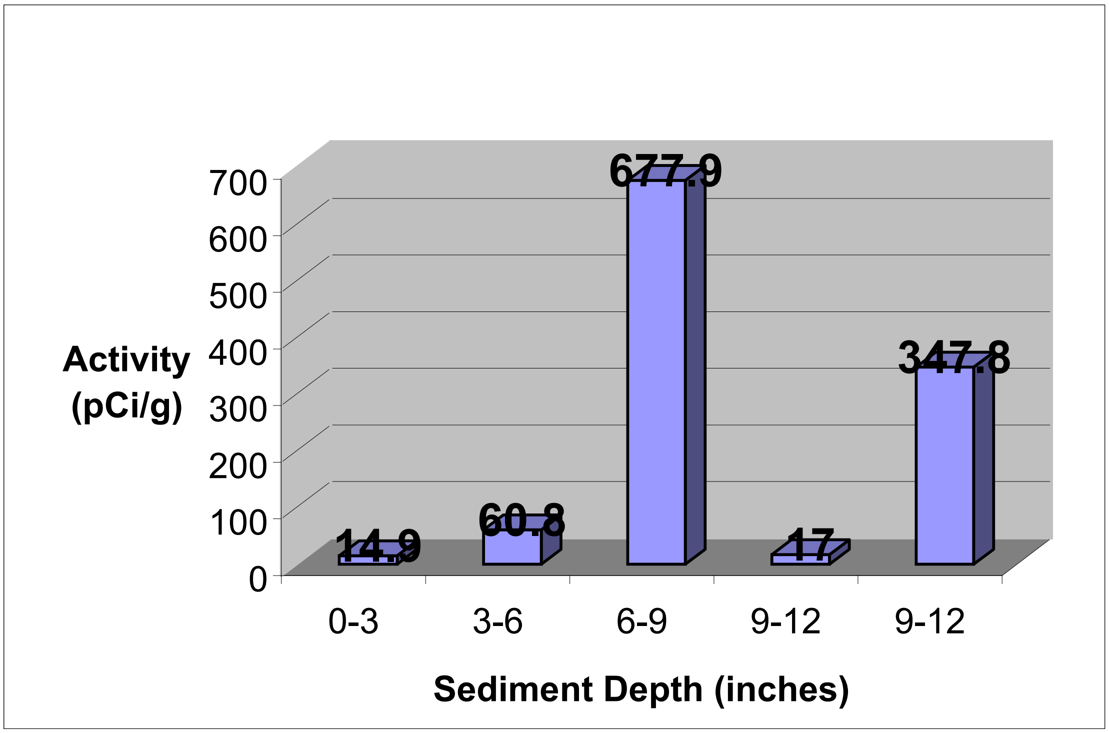
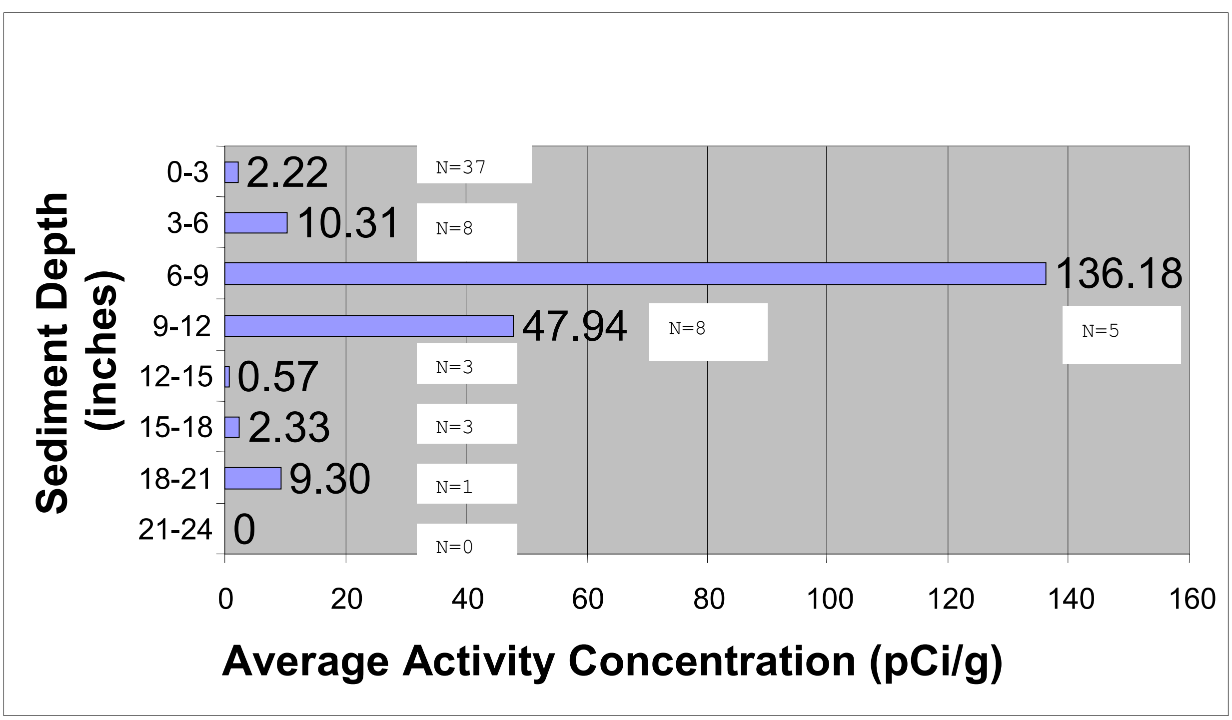


Figure 11 Offshore RCA Elevated Activities Lagoon Survey Results



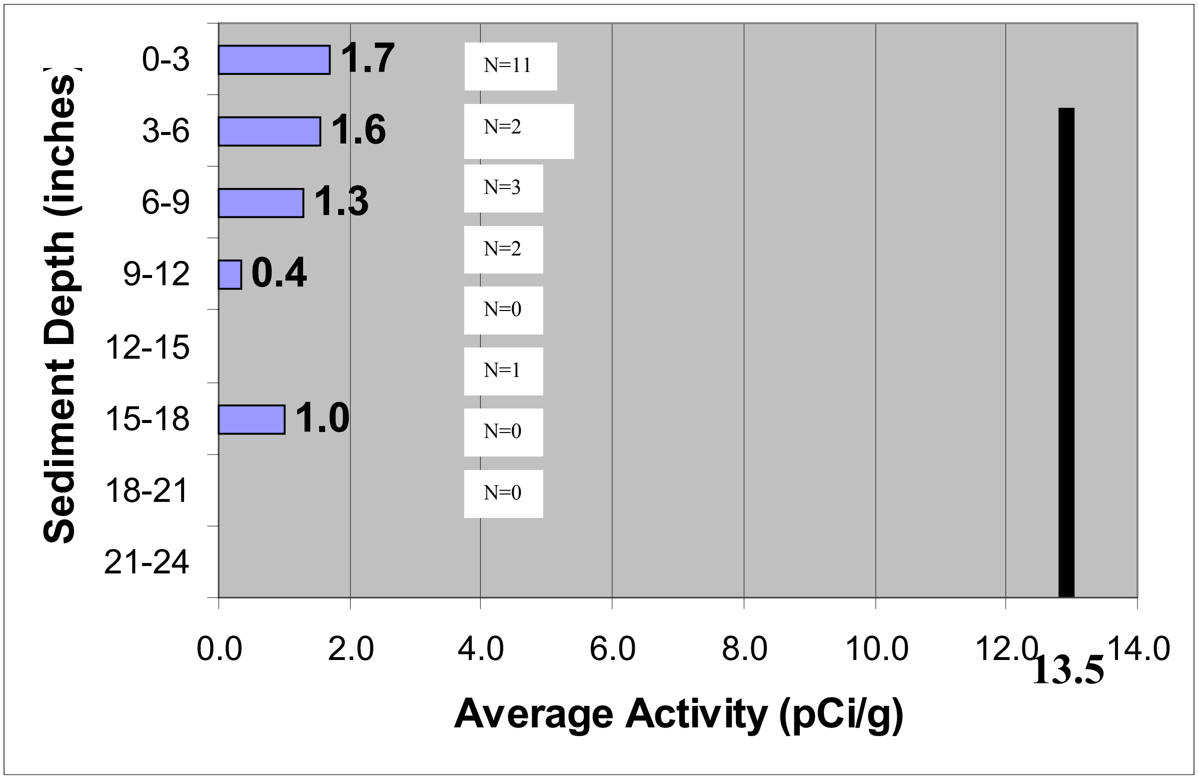


Figure 13 Sand Island Stratification Lagoon Survey Results

H-8.2 Sand Island Offshore Results

A second area of concern was the area offshore of Sand Island. According to the HSA, debris from the aborted STARFISH event was found on and around Sand Island. A total of 19 laboratory samples from around the outer perimeter of the island were prepared and analyzed from 11 cores. The average activities are listed above in Figure 31. The average activities are well below the soil cleanup level, with the single highest sample activity being 3.4 pCi/g found in the 0-3 inch depth range.

H-8.3 Johnston Atoll excluding RCA & Sand Island Offshore Results

Excluding the Offshore RCA & Sand Island data, the average activity for the remaining 113 laboratory samples prepared from 61 cores was calculated for the rest of the atoll. This TRU distribution with depth is shown below in Figure 32.

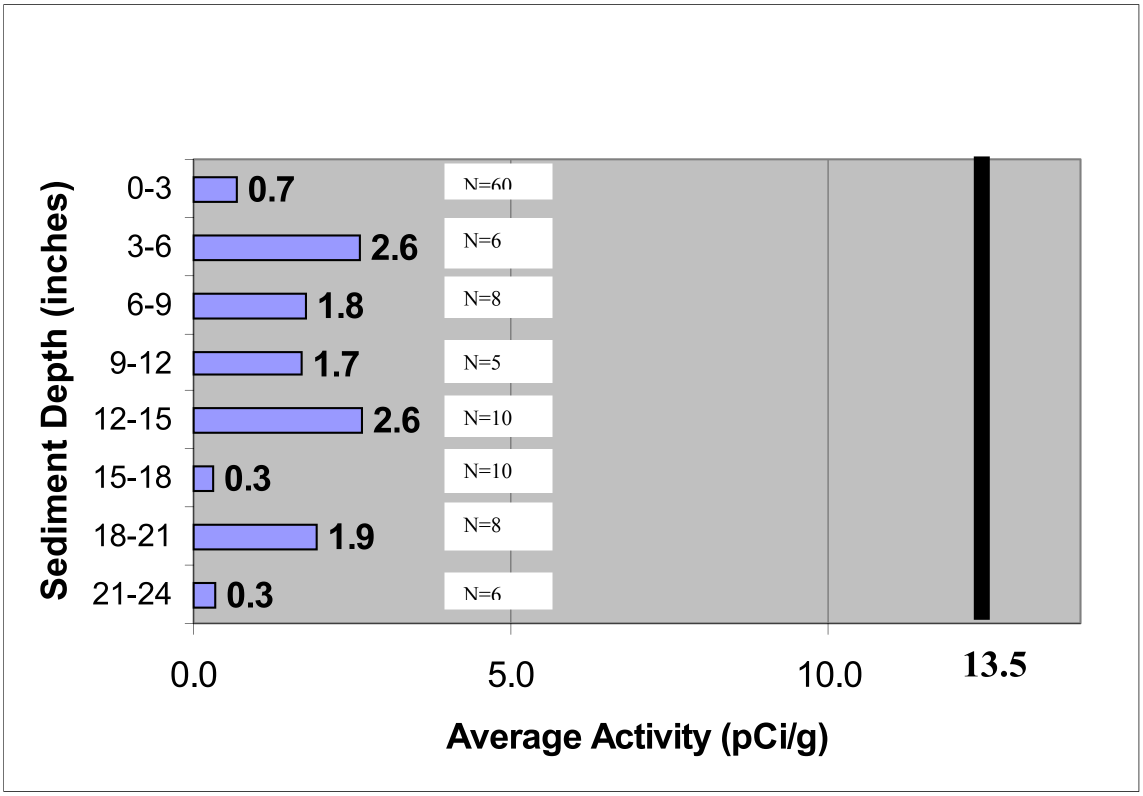


Figure 14 JA Stratification Less Offshore RCA & Sand Island Lagoon Survey Results

This analysis also shows that the average activity for the entire atoll, less offshore the RCA and Sand Island areas, is below the soil cleanup level. The highest sample activity found was 4.8 pCi/g in the 15-18 inch depth range.

H-8.4 Offshore Sand and North Island Results

An analysis was conducted of 12 laboratory samples prepared from 6 cores collected offshore Sand and North Island. This provided an estimate of sediment concentrations available to bottom feeding fish. The results are shown below in Figure 33.

The results show that the average activities are below the soil cleanup level of 13.5 pCi/g. The highest sample activity found was 3.4 pCi/g in the 0-3 inch depth range.

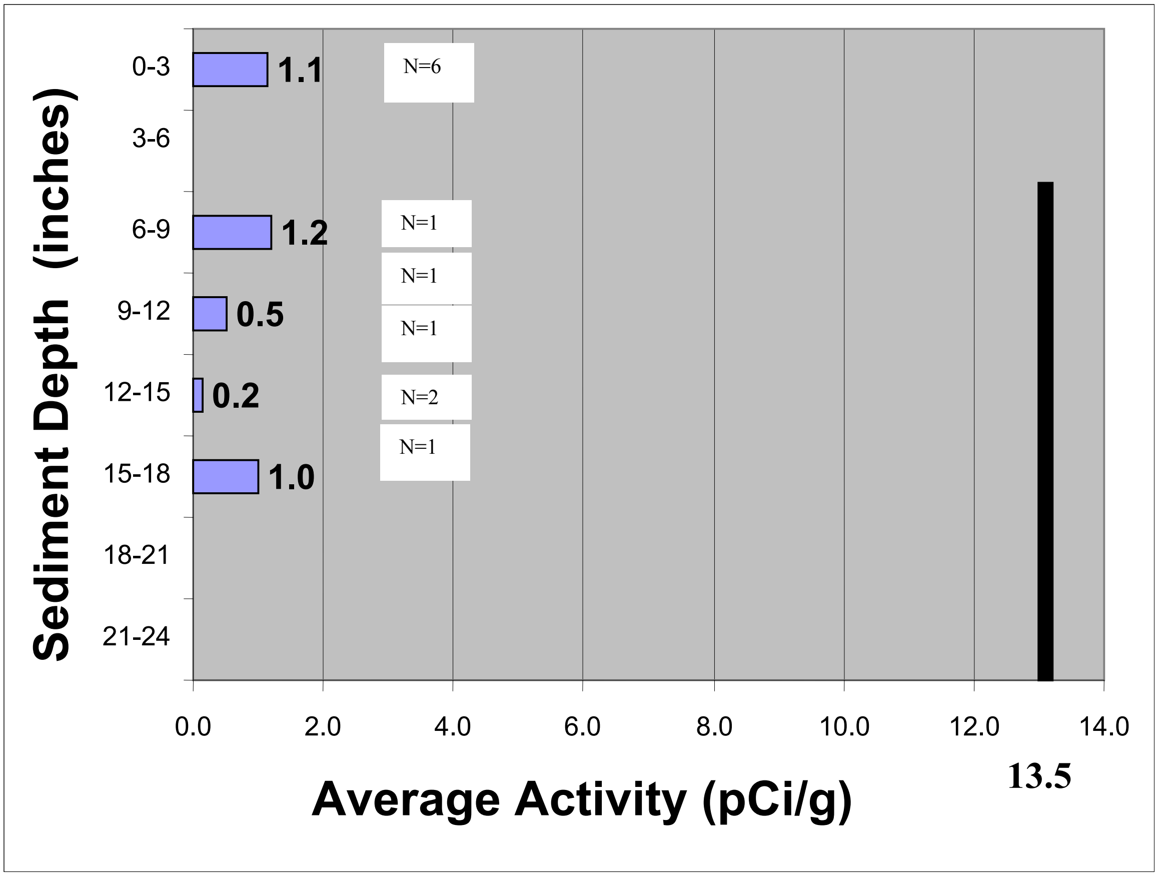


Figure 15 Offshore Sand and North Island Stratification Lagoon Survey Results

H-8.5 Previous Study Comparison

The DTRA made a comparison between the results of DTRA's core samples and previously collected cores by Noshkin in March 1980 from similar sites. The activities in the Noshkin Study were only given in $^{239/240}$Pu pCi/g. Since DTRA's activities were total TRU, a conversion was made using the $^{239/240}$Pu TRU ratio of 7.89E-01 to match units. The results are listed in Table H-2 below.

Table H-2 Comparison of Sediment Concentration For Similar Locations		
Sediment - Nov 2000 (DTRA) Activity $^{239/240}Pu$ (pCi/g)		Sediment – Mar 1980 (Noshkin) Activity $^{239/240}Pu$ (pCi/g)
0.394		0.039
1.026		1.070
3.392		1.650
1.657		0.004
3.392		0.015
AVERAGE	**1.972**	**0.556**
STANDARD DEVIATION	**1.371**	**0.763**

The next step was to conduct a statistical analysis to see if there are differences between the two sediment-sampling results. The statistical software package MINITAB© was used to conduct all the statistical analysis. The Mann-Whitney test was used due to the small sample size available.

MINITAB© tested the data for equal variance. Since the P-values (0.282 and 0.292) are greater than 0.05 (95% confidence interval (CI)), there is not sufficient reason to reject the null hypothesis (the variance in not equal), therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test (DTRA Report 2001b).

The Mann-Whitney test determines if there is a difference between the medians. Since the p-value (0.094) is not less than the chosen a level of 0.05, the conclusion is that there is insufficient evidence to reject the null hypothesis (the sample medians are different). Therefore, there is no difference between the medians. This analysis reveals that both sediment surveys found the same median activity at JA (DTRA Report 2001b).

The results show that both average activities are below the soil cleanup level of 13.5 pCi/g. MINITAB© verifies the DTRA's sample results are greater than Noshkin's, but within the appropriate standard deviations.

H-8.6 Conclusions

The objectives of the survey were met. Plutonium oxide concentrations both at the surface and sub-surface sediments were characterized, and comparison data was established for biological sampling. Only 5 out of 197 samples showed elevated activities above the soil cleanup level of 13.5 pCi/g. Only one was on the surface (0-3 inch depth) with its activity just above the soil cleanup level. The possible hazard to lagoon biota is therefore minimal. The results show that the highest concentrations are at sediment depths between 6-12 inches.

Annex I BIOTA SURVEY

I-1 Introduction and Overview

The objective of the biota survey was to quantify plutonium oxide and other radionuclides in selected reef fishes and macroalgae at selected sites within the JA lagoon. This biota survey follows the completion of the sediment survey conducted by Environet, Inc. and ADL during November 2000. This sediment survey provided a map of sediment radioactivity measurements against which the biota survey was planned. The data collected from this biota survey was used to determine the estimated radiation dose to fish, to humans consuming the fishes, to the green sea turtle consuming the algae, and to the Hawaiian monk seal consuming the fish. A complete discussion to include all data and calculations can be found in DTRA Report 2001a.

Dr. Philip S. Lobel (Boston University) and Lisa Kerr Lobel (University of Massachusetts, Boston) collected and prepared the biota in January 2001. Fish were collected northwest of the RCA to determine the maximum-possible-exposed fish dose. Fish were collected from Donovan's Reef and Hawaii to provide a baseline measurement assessment. Macroalgae samples were collected for food pathway analysis for the green sea turtle off the southern side of JI, which is a known feeding location.

Subsequent laboratory analysis was conducted by ORNL, Grand Junction, Colorado. Fish, viscera, and algae samples were analyzed by alpha spectrometry for ^{241}Am, ^{244}Cm, ^{238}Pu, $^{239/240}$Pu, and ^{242}Pu. This biological sampling was done to complete the analysis of radionuclide uptake and effects on the species around JA. Original sampling from 1995 was not appropriate for complete analysis of the effects of radionuclides on the animals around JA.

I-2 Summary of Selected Survey Sites

Six survey sites were selected for the collection of biota (fish and algae); maps are included in Appendix A of the DTRA Report 2001a. Summary discussions of the rationale used for each survey site chosen are included below. Table I-1 provides a brief description of each site and its GPS location.

I-2.1 North of the RCA on JI

After the BLUEGILL PRIME event, remedial action included constructing a ramp on the northwest corner of the launch area using contaminated soils. The primary focus of this sampling effort was the area northwest of the RCA where the ramp was constructed after the BLUEGILL PRIME event. Results from previous sediment samples informally taken from undocumented locations north of the RCA in 1999 were less than the established cleanup level of 13.5 pCi/g. Results from the sediment survey show that five samples from three cores taken from the lagoon north of the RCA exceed 13.5 pCi/g (DTRA 2001b). Fish and algae samples were collected; Table I-2 lists the number collected.

I-2.2 South Shore of Johnston Island (Turtle Site)

This area is the main location where green sea turtles have been observed feeding. The sediment survey did not identify any significant radioactivity near this site. This site was very shallow with a rubble bottom and without significant reef structure. Consequently, macroalgae flourish due, in part, to a general decreased standing population of fishes. Thus, macroalgae was sampled here. Fish and algae samples were collected; Table I-2 lists the number collected.

I-2.3 Sand Island

The results listed in the Outer Island Survey Report (USACOE 1999) found only 3 out of 383 samples above 13.5 pCi/g TRU of coral on Sand Island. The FIDLER walkover data found only one small-localized area (<4 m^2) of elevated activity on the southwest side of the island by the old U.S. Coast Guard barracks. These results supported a less aggressive sediment sampling effort in the lagoon surrounding the island. However, because a small-localized area of contamination was found, and the fact that the HSA documented debris falling onto Sand Island, lagoon sediment samples were taken 360 degrees around the island. No underwater hot spots were discovered (DTRA, 2001b). Fish samples were collected; Table I-2 lists the number collected.

I-2.4 Blue Hole (North Island)

North and East Islands were created after the nuclear testing era. The HSA found no previous history of radioactive contamination on either of these two islands. The Outer Island Survey Report (USACOE, 1999) documented the lack of contamination on East and North islands. Based on this information, the lagoon sediment sampling requirement in these areas was significantly reduced. If no contamination is on the surface of an island made from the sediments surrounding it, the chance of contamination being in the lagoon bottom around these areas is very small. This was confirmed by the sediment survey which did not identify radioactivity above the level of concern. North Island's reef east of the "Blue Hole" was one of two locations where fish (surgeonfish, *Ctenochaetus strigosus*) were sampled previously (DTRA 2001a). Fish samples were collected; Table I-2 lists the number collected.

I-2.5 Donovan's Reef

The area referred to as "Donovan's Reef" is the shallowest reef located at the extreme northeast corner of the atoll. It is the farthest (approximately 5 miles) reef site from the JA islands and, therefore, far from the center of plutonium fallout. Fish and algae samples were collected; Table I-2 lists the number collected.

I-2.6 Hawaii

Hawaii was chosen as the reference site with collected specimens providing a measure of background comparison. The collection location was Kaneohe Bay, Oahu. Fish and algae were collected from this site, see Table I-2.

I-3 Sampling Strategy

Species were collected at five sites throughout the atoll and two in Hawaii. The locations, a species summary and the sample size used are provided below in Table I-1 and I-2.

I-3.1 Surgeonfish (*Acanthuridae*)

All surgeonfishes are herbivores but differ in whether they ingest sand. <u>Grazers</u> are species with thick-wall stomachs and ingest fine grain sand with algae. <u>Browsers</u> are species with thin-wall acidic stomachs and avoid sand ingestion.

Table I-1 Biota Sampling Sites

Short Name	Brief Description	GPS Location
N. of RCA	Northwest of the RCA; sediment survey identified four hotspots.	16° 43.892 N, 169° 32.534 W
Turtle Site	South shore of JI. Green Sea Turtle feeding area.	16° 43.820 N, 169° 31.705 W
Sand Island	Sand Island – Area of the wharf just west of the island. One of two previous fish collection sites.	16° 44.812 N, 169° 31.031 W
Blue Hole	North Island – East edge of reef commonly called "Blue Hole." One of two previous fish collection sites.	16° 45.810 N, 169° 30.818 W
Donovan's	Donovan's Reef – East reef margin of the Atoll. Approximately 5 miles from JI.	16° 47.018 N, 169° 27.823 W
Hawaii	Hawaii – Kaneohe Bay, Oahu	6° 20.74 N, 157° 40.8 W

Goldring Surgeonfish, *Ctenochaetus strigosus* (C. Strig), **Kole** or **Golden-eyed**

A herbivore grazer feeding mainly on micro-algae mixed thickly with fine grain sand particles. It digests algal food mainly by mechanical trituration in a thick-wall stomach (Lobel and Kerr 2000). Sand is processed through the gut along with food.

The kole has a population difference between different JA sites, suggesting that there is a high degree of local isolation. It is the most abundant species overall in the lagoon with an estimated population size of 1,650,300 individuals (Irons et al. 1989). It is also one of the top two fishes taken by fishermen on the atoll with a typical annual harvest of about 1,200 fish.

The kole was collected at all sites except Hawaii and served as the main fish bioindicator since it is the most numerous species in JA. Fish species with this specific tropic specialization are ones known to be the best accumulators of radionuclides in the reef environment (Noshkin et al. 1997a). Noshkin et al. (1997a) also determined that "(radionuclide) concentrations associated with surgeonfishes were always greater than levels in flesh of goatfish and generally exceeded or were equivalent to the levels in mullet." The emphasis on *C. Strig* is based upon the existing data set and the fact that this is the most common and easily collected species at JA.

C. Strig was first sampled in May 1995 because individual fishes were found having various deformities. These specimens were analyzed for radioactivity by ORNL in July 2000. A total of 20 specimens, collected off Sand and North Island in 1995, were analyzed revealing that 35% of the analyzed samples had detectable levels of ^{241}Am and ^{238}Pu in their tissues and 70% had detectable levels of $^{239/240}$Pu. There was no statistical difference in the radioactivity of deformed vs. normal fish, see Appendix B of DTRA report 2001a.

Convict Surgeonfish, *Acanthurus triosegus sandvicensis* (*A. Trig*), **Manini**

A herbivore browser feeding mainly on fine filamentous algae while avoiding ingestion of carbonate sand particles. It digests alga food mainly by acid-lysis in a thin-wall and distensible stomach (Lobel and Kerr 2000).

A. Trig is one of the top ten fishery species and has an estimated population size of 599,600 individuals in the lagoon, making it the tenth most abundant fish (Irons et al. 1989). Radiological data for this same species in the Marshall Islands was collected by Noshkin et al. 1997 and allowed for a direct comparison of results.

I-3.2 Goatfish (*Mullidae*)

These fish are predatory benthic carnivores feeding on all types of small invertebrate, crustaceans, fish prey, and other animals that are usually buried in sand. They use their specialized chin-barbels, which are covered with taste buds to detect prey hidden in sand. These fishes often swallow large amounts of sand with their food. There are 7 species (2 genera) of goatfish at JA. These fish are one of the popular fishery species and among the 10 most frequently caught at JA.

Goatfish were more difficult to find and collect than surgeonfish at every site and especially in Hawaii. This is because they are less numerous than herbivorous surgeonfishes and are also more intensely fished. Collection focused on *Mulloidichthys flavolineatus*, which is the same species collected in the Marshall Islands by Noshkin et al. (1997a, reported by the synonym *Mulloides samoensis*). Noshkin et al. (1997a) also collected other goatfish species in fewer quantities.

Yellowstripe Goatfish, *Mulloidichthys flavolineatus* (*M. Flavo*), **Weke ‘a**

This species population has been estimated to be about 188,900 individuals in the lagoon and is one of the 10 main fishery species at JA (Irons et al. 1989). This species usually displays a black spot on its side, below the first dorsal fin.

Yellowfin Goatfish*,* *Mulloidichthys vanicolensis* (*M. Vani*), **Weke ‘ula**

This species is very similar to *M. flavolineatus* but without the black spot on the side. Both species aggregate in resting groups and mostly feed at night.

Manybar Goatfish, *Parupeneus multifasciatus* (*P. Multi*), **Moana**

This species is one of the 10 most common species at JA. An estimated population of 61,850 fish live in the lagoon.

Doublebar Goatfish*, Parupeneus bifasciatu* (*P. Bifas*), **Mumu**

This species is one of the main fishery species at JA. An estimated population of 48,000 fish live in the lagoon.

I-3.3 Macroalgae (*Chlorophyta* - green algae)

Algae are known to be responsive to the soluble phase of constituents in the ambient medium but they do not respond to elements associated with particulate matter (Pentreath 1985, Sam et al. 1998). Even so, algae were found to be effective bio-indicators for monitoring marine radioactivity levels. Around JA, macroalgae are most abundant in the area along the south shore, near the JACADS facility. This is due partly to the lack of reef structure in this area. Thus, there are fewer herbivorous fishes, which allow algae to become macro. Algae at other sites around the atoll had less mass and abundance. *Caulerpa serrulata* was the only species collected and used for analysis.

I-3.4 Green Corkscrew Alga, (*Caulerpa serrulta,* (*Caul serra*))*,* **Limu**

This species is the dominant macroalga in the JA lagoon, especially in the winter season. In the area along the south shore where green sea-turtles are most frequently observed, it was the only macroalga found and it was present in abundant large mats. The green sea turtle, *Chelonia mydas*, is one of only two herbivorous sea turtle species, and it is known to eat *Caulerpa serrulata* algae (Marquez 1990).

I-4 Selection of Sample Size

To determine the sample size necessary to statistically test for concentration differences in biota between sites, radiological data from the May 1995 sampling of *Ctenochaetus stigosus* were used. A power analysis was used to determine the minimum sample size required to detect differences of 1 pCi/sample in radionuclide concentration between survey collection sites using an analysis of variance (ANOVA) test. Based on the isotope with the largest degree of variability ($^{239/240}Pu$), a minimum sample size of ten fish would be able to detect a significant difference at an alpha = 0.05 with a power (1 - β) of around 0.94. Generally a power greater than 0.80 is considered desirable (Zar 1984).

A Dunnet's multiple comparison test was used to determine if any of the JA samples differed significantly from the reference sites at Donovan's reef and in Hawaii. It is also important to note that a different result is obtained using the variance for ^{241}Am and $^{239/240}Pu$ to calculate minimum sample sizes. It shows that with sample sizes as small as five fish, the probability of detecting significant differences at the 0.05 level is greater than 99% (power = 0.99). Thus, we used the more conservative minimal sample size of 10 specimens based on the $^{239/240}Pu$ data.

I-5 Sampling Methods

The Lobels conducted the field collection effort. Specific sampling site coordinates were determined using a GPS navigation instrument. Underwater scuba diving equipment was utilized to collect fish and algae specimens. Individual fish specimens were speared and sealed in a bag. Collection focused on the largest and therefore presumably the oldest fishes at a site. Macroalgae were uprooted by hand (roots and all) and placed into individual labeled bags and sealed underwater. Each specimen was taxonomically identified to species and labeled appropriately. During field collection, a visual survey was conducted of the site and an effort made to assess any abnormal animals or otherwise unusual situations present. None were noted.

Once collection was complete, specimens were stored on ice until transferred to the laboratory for preparation and dissection. Table I-2 below lists the number of sample species collected from each of the six survey sites.

Table I-2 Biota Sample Numbers by Location

SITE	***C. Strig* (KOLE)**	***A. Trios* (MANINI)**	**GOATFISH (All species)**	**(*Caul Serra*) ALGAE**
1. North of RCA	10	10	5	5
2. Turtle Site	10	--	--	5
3. Sand Island	10	--	5	--
4. Blue Hole	10	--	--	--
5. Donovan's	9	10	5	5
6. Hawaii	--	7	1	5
Total Specimens	**49**	**27**	**16**	**20**

I-6 Sample Processing

Fish samples were blot-dried and weighed whole, then eviscerated with the viscera being weighed separately. The standard length and mass (g) of each fish were measured. Each specimen was carefully visually assessed macroscopically for the identification of deformities or lesions. None were noted. The fish were also dissected to remove their otolith bones. The otoliths can be used to determine the age of a fish. These otoliths were archived for possible future analysis. Algae samples were also blot-dried, weighed whole, sealed in plastic and frozen until shipped to ORNL for radiological analysis.

I-7 Laboratory Analysis

Laboratory analysis of the fish and algae was performed by ORNL. Both the eviscerated fish and its viscera were analyzed separately for radioactivity. The separation was done to allow different human and biota risk assessments to be completed.

The entire sample was first dry ashed to prepare it for analysis; therefore, no duplicate analysis was performed. Samples were placed in tared platinum crucibles and controls and internal standards were added to the batch.

The samples were fused and the flux from the fusion dissolved in 1000 mL of 1 M HCl. The sample was split into two equal aliquots after the dissolution. One 500-mL aliquot was set aside and analysis was continued and completed using the other aliquot. Additional americium purification from rare earth elements was also completed before analysis. Samples were analyzed by alpha spectrometry for presence of ^{241}Am, ^{244}Cm, ^{238}Pu, $^{239/240}$Pu, and ^{242}Pu using ORNL procedure RC-19 R06.

Analysis conducted on the data focused on answering six questions:

1) How do the sites (North of the RCA, Turtle Site, Blue Hole, Sand Island, and Donovan's Reef) on JA compare to each other (as plutonium oxide muscle concentration)?
2) How does JA compare to other sites in the U.S. (as plutonium oxide muscle concentration)?
3) What is the radiological dose to the fish?
4) What is the radiological dose to humans from consuming fish from JA?
5) What is the radiological dose to the green sea turtle from consuming macroalgae at JA?
6) What is the radiological dose to the Hawaiian monk seal from consuming fish at JA?

I-8 Results and Data Analysis

I-8.1 Introduction

The following discussion will explain the analysis rationale and method, any assumptions, the testing of those assumptions, the calculations, and the conclusions. This discussion focuses on answering the first question (section I-7), how do the sites (North of the RCA, Turtle Site, Blue Hole, Sand Island, and Donovan's Reef) on JA compare to each other (as plutonium oxide muscle concentration)? The data used for the analysis can be found in the DTRA report 2001a.

I-8.2 Data Analysis

Intercomparison between JA sampling locations - Graphical Review of Viscera Activity to Total Activity Ratio

Rationale: The ratio of viscera activity to total activity is used because it illustrates where the plutonium oxide resides in the fish. This analysis determines (visually) if there are equalities between species or locations. The average and median ratios across the entire atoll are shown in Figure 34. The ratio is used for plutonium oxide tissue partitioning, tissue concentration calculations and comparisons, later dose calculations, and the ratio is independent of total activity (small activities can be compared to large activities). The equation is shown below and raw data is in DTRA Report 2001a.

$$\text{Viscera Ratio} = \frac{\text{Viscera Activity}}{(\text{Viscera Activity} + \text{Eviscerated Activity})}$$

Method: The method was to plot the average and median viscera activity to total activity ratios by sampling location and species (Figure 34) for JA and Hawaii. The error bars for the average are at the 95% CI.

Conclusion: Visual inspection of Figure 34 shows that there are differences and similarities between column sets (areas, locations and species). Specifically, the data from Donovan’s Reef and Hawaii are similar to each other as well as surgeonfish species from north of the RCA. A statistical comparison follows.

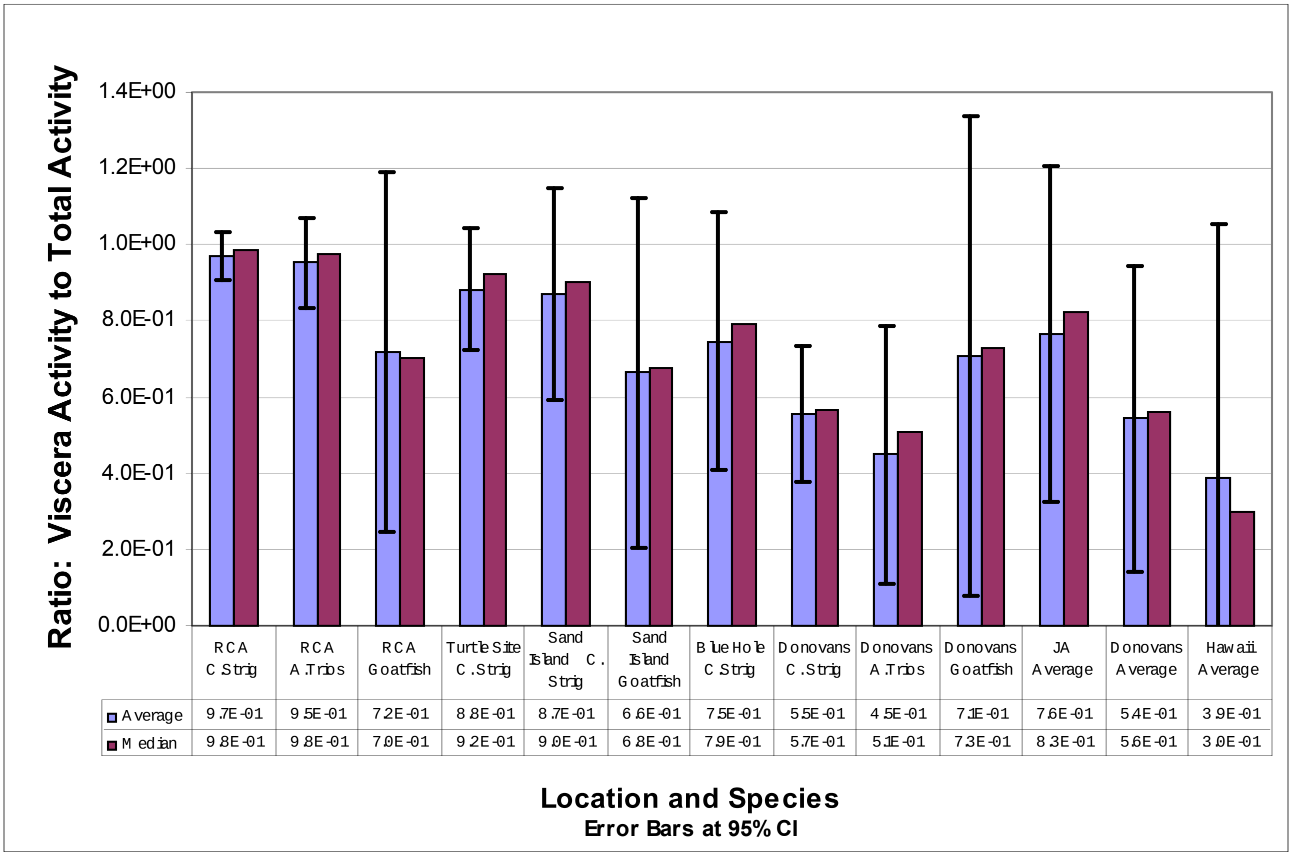


Figure 16 Intercomparison Between JA Biota Sample Locations and Species

I-8.3 Statistical Analysis for Inter-comparison between Surgeonfish Species

Rationale: The first analysis determines if there are differences between the two control sites, Donovan’s Reef and Hawaii. The next analysis determines if there are differences between two different species of surgeon fish (C. Strig and A. Trios) collected at both Donovan's Reef and north of the RCA. Each site will be analyzed for species equality.

Method: To test this, a statistical analysis was conducted to see if there is a difference between samples. The raw data used for this analysis is shown in the tables within each of the following subsections. The statistical software package MINITAB© was used to conduct all the statistical analysis. The Mann-Whitney test (also known as the two-sample Wilcox rank sum test) was used due to the small sample size available. The Mann-Whitney test tests the equality of two population medians, and calculates the corresponding point estimate and confidence intervals. The hypotheses are:

H0: h1 equals h2 versus H1: h1 is not equal h2, where h is the population median and H0 is the null hypothesis

Assumptions: An assumption for the Mann-Whitney test is that the data are independent random samples from two populations that have the same shape (hence the same variance) and a scale that is continuous or ordinal (possesses natural ordering) if discrete. Therefore, a variance test must first be conducted to perform hypothesis tests for equality or homogeneity of variance among the two populations using an F-test and Levene’s test. The test for equal variances generates a plot that displays Bonferroni 95% confidence intervals for the response standard deviation at each level. The data must pass at least one of the Equal Variance tests before the Mann-Whitney test will be started.

I-8.4 Donovan's Reef and Hawaii

Raw Data: The viscera ratio ($^{239/240}$Pu in the viscera to total $^{239/240}$Pu) in the same species is calculated and is shown in Table I-3 for Donovan's Reef and Hawaii.

Equal Variance Test Interpretation: Since the P-Values (0.077 and 0.251) for both the F-Test and Levene's Test are greater than 0.05 (95% CI), there is not sufficient reason to reject the null hypothesis, therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test.

Mann-Whitney Test: The Mann-Whitney test determines if there is a difference between the medians. The data for Donovan's Reef fish and Hawaii fish is shown below in Table I-3.

Table I-3 Donovan's Reef & Hawaii A. Trios Viscera Pu Ratio Data		
Donovan's Reef A. Trios	viscera ratios	Hawaii A. Trios
0.50		0.41
0.56		0.00
0.27		0.63
0.63		0.28
0.61		1.00
0.39		0.15
0.52		0.30
0.42		
0.07		
0.53		

The Mann-Whitney Test Interpretation: There is no difference between locations. Since the test's significance score (0.46) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal. This analysis reveals that A. Trios is equal in their uptake of plutonium oxide at Donovan's Reef and Hawaii.

I-8.5 Donovan's Reef

Raw Data: The viscera ratio for surgeonfish is calculated and is shown in Table I-4 for Donovan's Reef.

Table I-4 Donovan's Reef Surgeonfish Viscera Pu Ratio Data		
C. Strig		A. Trios
fish (viscera ratio)		fish (viscera ratio)
0.43		0.50
0.64		0.56
0.57		0.27
0.64		0.63
0.45		0.61
0.63		0.39
0.56		0.52
0.43		0.42
0.63		0.07
		0.53

Equal Variance Test Interpretation: Since the P-values (0.084 and 0.313) for both the F-Test and Levene's Test are greater than 0.05 (95% CI), there is not sufficient reason to reject the null hypothesis, therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test.

The Mann-Whitney Test Interpretation: There is no difference between fish species. Since the test's significance score (0.09) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal. This analysis reveals that C. Strig and A. Trios are equal in their uptake of plutonium oxide at Donovan's Reef.

I-8.6 North of the RCA

The area north of the RCA had the same two fish species collected.

Raw Data: The viscera ratio for surgeonfish is calculated and is shown in Table I-5 for the area north of the RCA.

Table I-5 North of the RCA Surgeonfish Viscera Pu Ratio Data

A. Trios		C. Strig
Viscera ratio		Viscera ratio
0.91		1.00
0.99		0.99
0.95		0.98
1.00		1.00
0.99		0.99
0.80		0.96
0.97		0.98
0.98		0.99
0.99		0.91
0.95		0.92

Equal Variance Test Interpretation: Since the P-values (0.080 and 0.406) for both the F-Test and Levene's Test are greater than 0.05 (95% CI), there is not sufficient reason to reject the null hypothesis, therefore the two samples have equal variances and meet the required assumption for the Mann-Whitney test.

Mann-Whitney Test Interpretation: there is no difference between fish species. Since the test's significance score (0.43) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal between C. Strig and A. Trios from north of the RCA. The conclusion from both this site and Donovan's Reef is that C. Strig and A. Trios are equal in their uptake in plutonium oxide.

I-8.7 Fish Size Comparison

Rationale: The next level of comparison is to determine if the size of the fish impacts the viscera activity ratio. Since the Donovan's Reef data set has been shown to have equality between the species and has a large number of samples available (since the surgeonfish species are equal, both can be used for this analysis) only the Donovan's Reef data will be used.

Method: The same statistical method for comparison will be used as before. The line separating the "small" fish and "large" fish will be 100 g in mass.

Assumptions: A small fish is one less than 100 g and a large fish is greater than 100 g.

Raw Data: The raw data for fish size comparison is presented in Table I-6 below.

Table I-6 Donovan's Reef Fish Size and Plutonium Oxide Ratios Data			
Small Fish Data Set <100 g		Large Fish Data Set >100 g	
Small Fish Mass (g)	Small Fish Ratio	Large Fish Mass (g)	Large Fish Ratio
50	0.63	153	0.53
50	0.64	155	0.39
50	0.56	172	0.42
54	0.57	184	0.52
55	0.45	193	0.50
59	0.43	196	0.07
66	0.63	199	0.61
67	0.43	203	0.56
71	0.64	209	0.63
		227	0.27

Equal Variances Test Interpretation: Since both P-values (0.095 and 0.346) are greater than 0.05 (95% CI), then the assumption of equal variance is valid and meets the requirements of the Mann-Whitney Test.

Mann-Whitney Test Interpretation: There is no difference between small and large fish. Since the test's significance score (0.09) is greater than 0.05, the conclusion is that there is insufficient evidence to reject H0; therefore, the medians are equal. This analysis reveals that small and large size fish are equal in their uptake of plutonium oxide at Donovan's Reef.

Conclusions: There is no difference between species (C. Strig and A. Trios) at two different sites. There is no difference between the smaller and larger fish with respect to their viscera to eviscerated fish activity ratios. These results allow comparison to other sites regardless of fish size and species type.

I-8.8 Muscle Tissue Concentration Calculations

Rationale: To allow for comparison to other locations cited in the literature, the muscle tissue concentration of $^{239/240}$Pu is required. A literature review discovered partitioning values for plutonium in fish (Noshkin 1980). The next step is to apply Noshkin's partitioning value for fish to the collected JA fish. Noshkin's data table is reproduced in part below as Table I-7. This data table was selected because it matched for plutonium, was also in a South Pacific atoll environment, and used the same fish species. The equations for this calculation can be found in DTRA report 2001a.

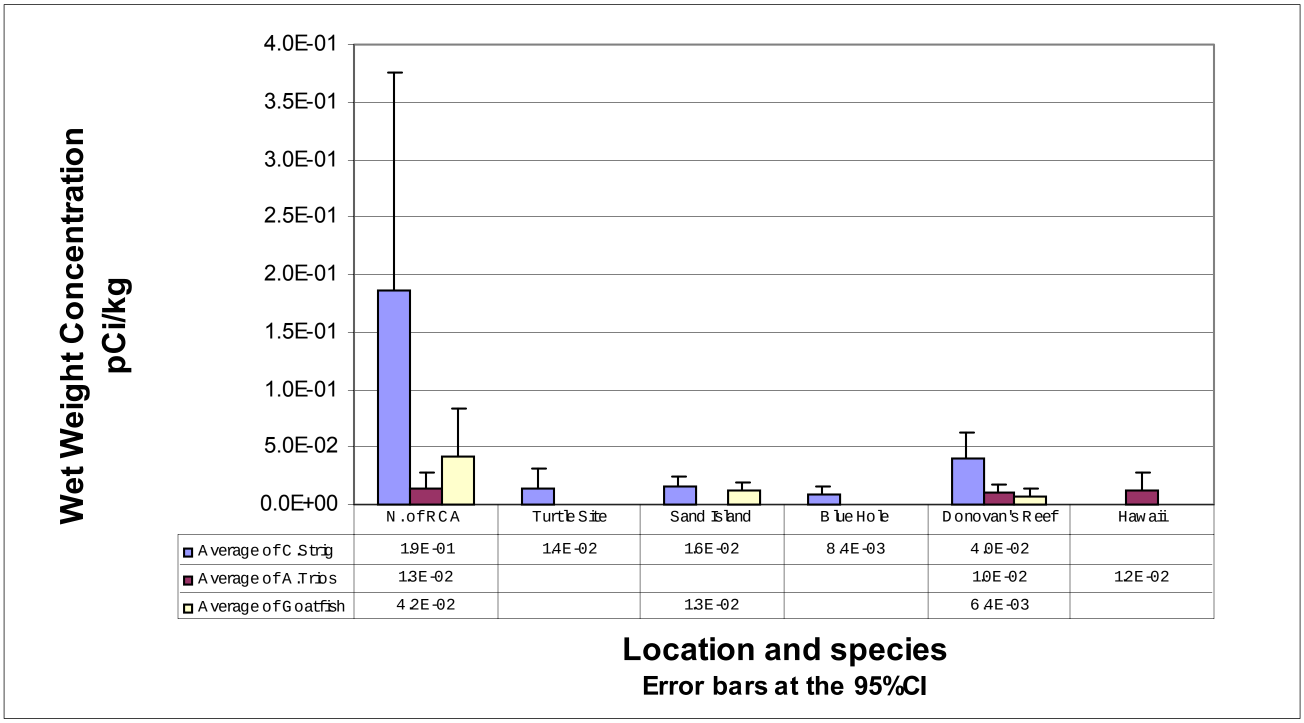
Table I-7 Data Table from Noshkin 1980 p. 400			
Reconstructed Concentrations of Radionuclides in Bikini Atoll Fish	A (Muscle)	B (Muscle & Skin)	C (Muscle, Skin, & Bone)
$^{239/240}$Pu (pCi/kg) in Convict Surgeon Fish	0.11	1.20	2.81
^{241}Am (pCi/kg) in Convict Surgeon Fish	0.026	0.32	0.48
$^{239/240}$Pu (pCi/kg) in Goatfish	0.073	0.57	0.89
^{241}Am (pCi/kg) in Goatfish	0.030	0.20	0.41

I-8.9 Application of the Partitioning Value

The viscera and the eviscerated fish were analyzed separately. With this division of the fish, the Noshkin ratio with the eviscerated fish activity can accurately predict the muscle concentration. The partitioning value for surgeon fish is 4.5% and 7.5% for goatfish. Complete analysis can be found in the DTRA Report 2001a.

The summary of muscle concentrations by area and species are shown below in Figure 35.

Conclusion: Therefore, to answer the first question about how the sites compare, Figure 35 shows how plutonium oxide muscle concentrations compare between sites.



	N. of RCA	Turtle Site	Sand Island	Blue Hole	Donovan's Reef	Hawaii
Average of C. Strig	1.9E-01	1.4E-02	1.6E-02	8.4E-03	4.0E-02	
Average of A. Trios	1.3E-02				1.0E-02	1.2E-02
Average of Goatfish	4.2E-02		1.3E-02		6.4E-03	

Figure 17 Plot of $^{239/240}$Pu Muscle Concentration in Biota Samples for Comparison Between Locations Around JA

I-9 Site Comparison

The plutonium oxide muscle concentration can be compared to other sites in the other parts of the U.S. (Figure 36) (Robison et al. 1981). Figure 36 answers the second question (section I-7), how does JA compare with other sites.

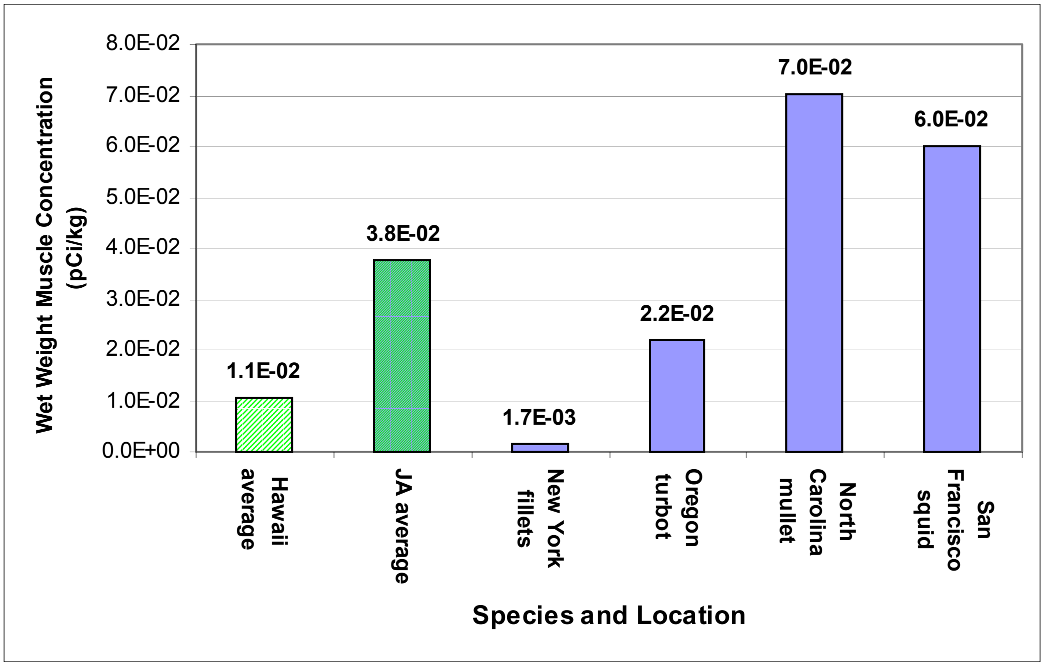


Figure 18 U.S. Comparison of $^{239/240}$Pu Muscle Concentration in Fish Muscle Tissue

I-10 Fish Dose Calculations

Rationale: To answer question 3(section I-7), calculating the radiological dose from the plutonium oxide to fish at JA is the goal. This calculation will allow comparison of the calculated values to International Atomic Energy Agency (IAEA) dose limits for animals.

Method: Calculation of the radiological dose to fish is done by determining the total energy absorbed per kilogram of tissue. The energy absorbed is the sum of all the particle's energies from each contributing isotope. Only the alpha energy is considered in this dose calculation. The gamma radiation emitted (60 keV) from these isotopes is approximately 2 orders of magnitude less than the alpha (5 MeV) therefore the gamma is negligible and was not considered. The complete set of calculations can be found in the DTRA report 2001a.

I-10.1 Gastrointestinal Tract Crossing

The first assumption to test is whether all the isotopes cross the gastrointestinal tract the same way. The method to test this is to see if the transuranic ratio (total alpha activity divided by ^{241}Am activity) changes between the viscera and the eviscerated fish. All the viscera's transuranic ratios were calculated and compared to the eviscerated fish's ratio for all the fish at JA in DTRA Report 2001.

Graphical Review: Figure 37 shows the viscera's transuranic ratios compared to the eviscerated fish's ratio along with the 95% CI error bars on the distribution of the ratios.

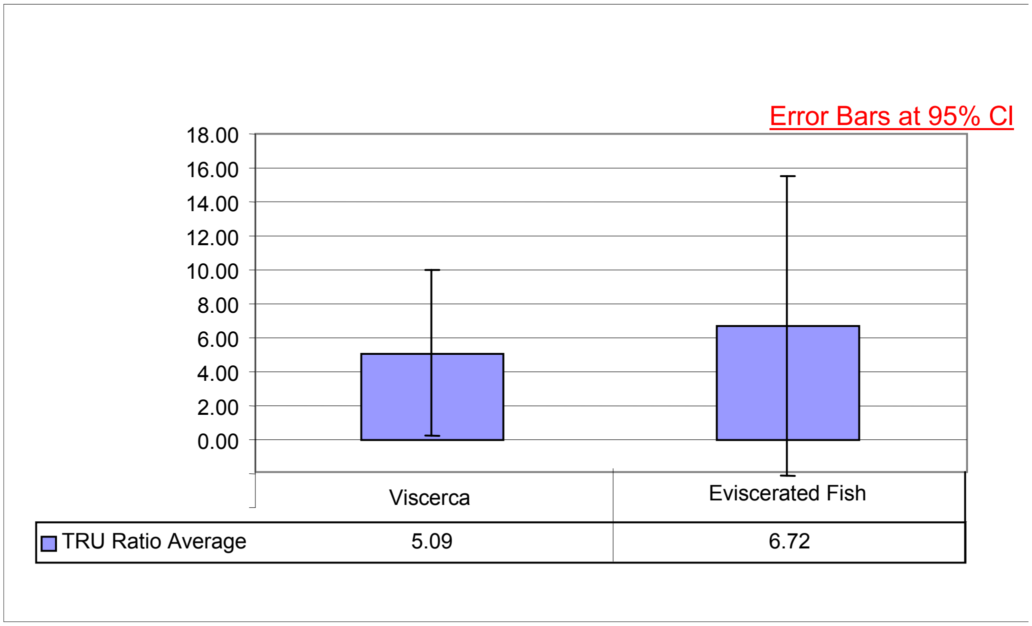


Figure 19 TRU Ratio Average for Viscera and Eviscerated Fish

Statistical Analysis: The same method used before will be applied to this analysis.

Equal Variance Test Interpretation: Since both P-values are less than 0.05 (95% CI), the assumption of equal variance is not valid and fails to meet the Equal Variance requirement.

Alternative Statistical Test: The 2-Sample T-test is used without assuming equal variances. The 2-Sample T-Test prefers to have a normal distribution on the data. Neither of these two data sets are normal in their distribution. However, data sets with sample sizes greater than 30 are considered large. This analysis uses 167 total samples, because the viscera results from sample number 88 were lost in shipment. Large sample sizes decrease the dependence upon normalcy.

Two-sample T Test Interpretation: The 95% CI (-3.10, 0.94) includes zero; therefore, it suggests there is no difference. The hypothesis test includes a P-value of 0.291, and 135 degrees of freedom. Since the P-value is greater than 0.05, there is no evidence for a difference in transuranic ratios between the viscera and the eviscerated tissue. This supports the assumption that the isotopes move across the gastrointestinal tract equally.

I-10.2 Dose Calculation

Using the individual isotope's activity in each eviscerated fish and the partitioning fraction into the tissue types (muscle, bone, and scales/skin), the total energy deposited in that tissue type can be calculated. The equation can be found in DTRA Report 2001a.

The ratio of tissue type to whole body weight for surgeonfish and goatfish is shown below in Table I-8 (Noshkin 1987). The values will be used to determine the radiological dose (energy absorbed per kg of tissue).

Table I-8 Fish Tissue Fractions by Mass

Name	Muscle	Bone	Scales/Skin
Surgeonfish	0.663	0.08	0.116
Goatfish	0.663	0.08	0.116

The summary average dose results are shown in Figure 38. The IAEA has an animal dose limit of 40 μGy/hr (Linsley 1997) (about 0.1 cGy/day or 36.5 cGy/yr). All the calculated doses are less than 1% of the established limit.

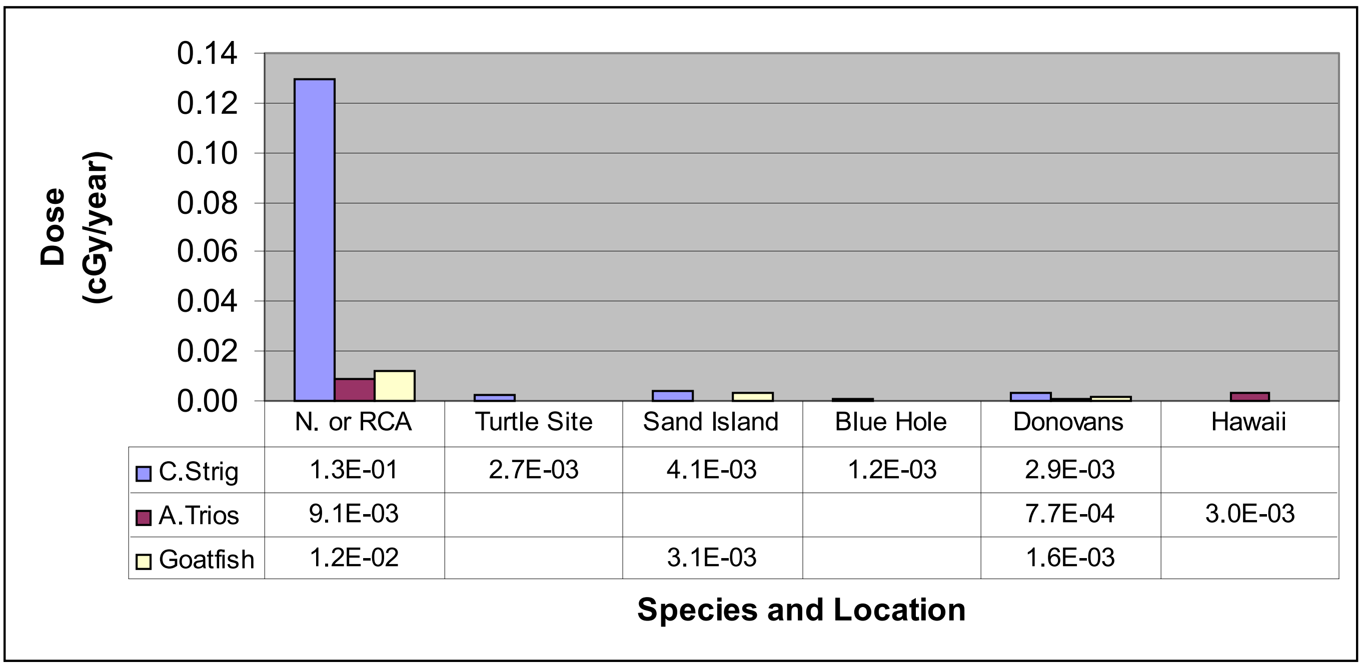


Figure 20 Average Dose to Fish Species at JA Locations

I-11 Human Doses

Rationale: The next step is to calculate the potential doses to humans from consuming the fish from JA and answer question 4 (section I-7). The fish from Donovan's Reef are omitted from this analysis. Fishing in Donovan's reef for bottom fish, like goatfish and surgeonfish, is normally not done since other (larger) fish species are available. Two scenarios are considered, consuming the entire fish and consuming only the muscle tissue. Both scenarios use equal amounts of fish intake of 200 g per day for the entire year (Noshkin 1987) and uses the ICRP Publication 30 dose conversion values.

Methods:

I-11.1 Muscle Tissue Scenario

The average concentration (TRU) of the muscle tissue, and of the entire fish was used at the 95% CI of the average (0.26 pCi/kg). The complete set of calculations can be found in DTRA report 2001a.

Table I-9 Human Dose Calculation from Fish Muscle Ingestion at JA

Ingested Mass	73,000 g/yr				
TRU intake (TRU)	18 pCi/yr				
Isotope	^{241}Am	$^{239/240}$Pu	^{244}Cm	^{242}Pu	^{238}Pu
Intake Amount (pCi)	3.4E+00	7.4E+00	1.3E+00	1.3E+00	4.7E+00
Intake Amount (Bq)	1.27E-01	2.75E-01	4.96E-02	4.97E-02	1.75E-01
Dose[1] (Sv)	2.79E-04	1.81E-06	9.42E-08	3.58E-07	2.58E-09
Dose[1] (rem)	2.79E-02	1.81E-04	9.42E-06	3.58E-05	2.58E-07
				Total Dose Annual (Sv)	***2.3E-06***
Mortality[2] Risk/Bq	2.6E-09	3.6E-09	2.0E-09	3.5E-09	3.5E-09
1 year Exposure Mortality Lifetime Risks					
	3.25E-10	9.99E-10	1.00E-10	1.71E-10	6.11E-10
				Total Risk	**2.2E-09**

[1] based on ICRP 30
[2] based on EPA 1999a

I-11.2 Entire Fish Scenario

The average concentration (TRU) of the entire fish around JI was used at the 95% CI of the average (196 pCi/kg). The calculations can be found in DTRA Report 2001a. The average values are used since the entire fish was consumed. The same calculation is done for consuming the entire fish. The results are shown below in Table I-10.

Table I-10 Human Dose Calculation from Entire Fish Ingestion at JA					
Ingested Mass		73,000 g/yr			
TRU intake (TRU)		14,300 pCi/yr			
Isotope	^{241}Am	$^{239/240}$Pu	^{244}Cm	^{242}Pu	^{238}Pu
Intake Amount (pCi)	3.2E+03	6.9E+03	6.8E+02	8.4E+02	2.8E+03
Intake Amount (Bq)	1.2E+02	2.6E+02	2.5E+01	3.1E+01	1.1E+02
Dose[1] (Sv)	1.7E-03	8.8E-05	1.8E-04	4.6E-07	1.5E-06
Dose[1] (rem)	1.7E-01	8.8E-03	1.8E-02	4.6E-05	1.5E-04
		Total Dose Annual (Sv)			0.002
Mortality[2] Risk/Bq	2.6E-09	3.6E-09	2.0E-09	3.5E-09	3.5E-09
1 year Exposure Mortality Lifetime Risks					
	3.0E-07	9.3E-07	5.0E-08	1.1E-07	3.6E-07
				Total Risk	1.8E-06

[1] based on ICRP 30
[2] based on EPA 1999a

Conservative Assumption Discussion: These scenarios assume that only benthic fish are consumed at JA and none of the common larger fishes inhabiting JA (tuna, mahi-mahi, ono) are eaten. Since the exact fraction of benthic fish in the human diet is unknown, this is considered the upper boundaries for each scenario. Plutonium does not bioaccumlate and plutonium concentrations actually decrease with trophic level (Noshkin 1979 and 1987). The large difference between the muscle tissue scenario and the entire fish scenario reflect the fact that plutonium oxide does not significantly cross the gastrointestinal tract (plutonium oxide is insoluble).

I-12 Green Sea Turtle Dose Estimate

Rationale: The Green Sea Turtle is a threatened species, inhabits JA and consumes macroalgae. A dose assessment is warranted to answer question 5 (section I-7). The calculated dose can then be compared to IAEA dose limits for animals.

Method: The turtle is not a human and therefore using human dose conversion factors from intake is inaccurate. The method used to calculate the equilibrium concentration of the transuranics inside the turtle and then the resulting dose from that concentration is summarized below. The equilibrium value is used since it is the maximum concentration possible in the animal resulting in the most conservative dose. Since "inside the turtle" means the activity that crosses the gastrointestinal tract, an f1 value must be applied. The f1 value is the fraction that crosses the gastrointestinal tract into the bloodstream. The equations and full discussion can be found in DTRA Report 2001a.

The 95% CI food intake for a turtle with a body mass of 99,760 g is 1,540 g (dry) or 30,800 g (wet). The DTRA used the 95% CI wet value of 30,800 g with a standard deviation of 12,600 g.

The average algae concentration is 0.05 pCi (TRU)/g with a standard deviation of 0.12 pCi/g which translates to about 2,200 pCi per day at the 95% CI and the Q value is 854 pCi in a 99,760-gram turtle. This equates to 3.2 x 10^{-4} Bq/g of tissue (1 Bq = 27 pCi). Using the maximum possible alpha emitter energy of 5.8 MeV/Bq the dose is calculated to be 0.001 cGy per year.

Conclusion: The dose is 0.001 cGy/year. This is insignificant (less than 0.003%) compared to the IAEA limit of 36.5 cGy/year (Linsley 1997) for reproductive effects in animals. If the quality factor (20 for alpha particles) is applied (this turns gray into sievert or calculates dose equivalent from dose), the corresponding dose to a human would be 0.2 mSv/year. Even treating the turtle as a human, the dose is well below (20% below) the general population limit of 1 mSv/year (10CFR20).

I-13 Monk Seal Dose Estimate

Rationale: Since the Hawaiian monk seal eats the JA fish, a dose assessment is warranted to answer question 6 (section I-7). The calculated dose can then be compared to IAEA dose limits for animals.

Method: The monk seal is close enough to humans that the ICRP human dose conversion factors using the whole fish ingestion scenario can be used. The 95% CI for consumption is calculated using the below equations.

Fish Consumption = 3,000 g/day (Greiner 2001)
Estimated Standard Deviation = 1,000 g/day (EPA 1993b)
Average TRU concentration of JA fish = 0.03 pCi/g
Standard Deviation of the TRU concentration = 0.09 pCi/g

Using these values yields 90 pCi/day ingested, an error of 272 pCi/day, and a 95% CI ingestion rate of 623 pCi/day intake rate or 227,000 pCi/year. The dose calculations are shown below in Table I-11.

Table I-11 Dose Calculation for the Monk Seal from JA Fish Consumption						
Ingested Mass			1.1E+06 g/y			
Annual TRU intake (TRU)			2. 3E +05 pCi/y			
Isotope		^{241}Am	$^{239/240}$Pu	^{244}Cm	^{242}Pu	^{238}Pu
Intake Amount (pCi)		5.0E+04	1.1E+05	1.1E+04	1.3E+04	4.5E+04
Intake Amount (Bq)		1.9E+03	4.0E+03	4.0E+02	5.0E+02	1.7E+03
Dose[1] (Sv)		2.7E-02	1.4E-03	2.9E-03	7.3E-06	2.5E-05
Dose[1] (rem)		2.7E+00	1.4E-01	2.9E-01	7.3E-04	2.5E-03
					Total Dose Annual (Sv)	**0.03**
Mortality[2] Risk/Bq		2.6E-09	3.6E-09	2.0E-09	3.5E-09	3.5E-09
1 year Exposure Mortality Lifetime Risks						
		4.8E-06	1.5E-05	8.1E-07	1.7E-06	5.8E-06
					Total Risk:	**2.8E-05**

[1] based on ICRP 30
[2] based on EPA 1999a

Discussion: Assuming the Hawaiian monk seal resides at JA year-round, eats only bottom-feeding fish, and feeds exclusively in the area of the lagoon immediately offshore of the RCA, calculations indicate that the dose to the monk seal would be about 10% of the annual limit set by the IAEA. These assumptions are very conservative; that is, they represent an improbable worst-case scenario.

The Hawaiian monk seal is a rarity at JA. The National Marine Fisheries Service recently evaluated data on the range of the Hawaiian monk seal and concluded that JA is "probably at or near the range boundary," and that "development of a seal subpopulation is hindered by the long distance from a source of immigrants and by a limited amount of undisturbed beach area on which the seals could rest" (NOAA 2001). Monk seals have been sighted at JA but their preferred habitat is in the northwestern Hawaiian Islands (the only known breeding area) approximately 500 miles from JA area (Marine Mammal Commission 2000, NOAA 1999). Monk seals introduced to JA from French Frigate Shoals did not remain at JA (Marine Mammal Commission, 2000). Hawaiian monk seals tend to stay near their breeding area year round with occasional excursions to deep water. Usually the seal will return within a few days to up to a month later (NOAA 1999, Earthtrust 2001, animalinfo 2001).

The second conservative factor is the ingestion total. The ingestion amount (0.2 pCi/g of fish) is set to protect an individual at the 95% CI, but examination of the JA fish concentration data set reveals that the large standard deviation (over three times the average) is driven by a few large samples which skew the results. The seal would have to feed only on the maximally contaminated fish in the lagoon near the RCA to achieve the calculated activity intake. Realistically, the seal would feed across the entire atoll and on a variety of other species. The normal diet of adult seals includes a variety of reef fish, eels, octopi and lobsters (NOAA 1999, Marine Mammal Commission 2000, Earthtrust 2001, Gilmartin 1983). “Although these food items are available nearshore, the dive data collected at Lisianski Island indicate that the animals regularly range away from the island to feed in the deeper waters of the outer reef and reef slope" (Gilmartin 1983, p. 7). The area of the lagoon outside the RCA is 1% of the total available feeding area of the lagoon. Thus, the dose estimate is probably high by a factor of 100. Furthermore, bottom-feeding fish in the area weigh on the order of 100 g each, so consuming 30 fish per day would quickly lead the seal to expand its feeding area or to consume other (non-bottom-feeding) fish less likely to contain plutonium.

Thirdly, the Hawaiian monk seal's average body weight is 400-600 lbs, two to three times greater than the weight and/or mass of the human model used for the seal's dose calculation. Since the dose is dependent upon the mass of the organism, this is a dose overestimation by a factor of two or three.

Lastly, the dose is actually distributed over a 50-year life span but by convention is assigned during the year of the intake. Since a Hawaiian monk seal's typical life span is 20 to 30 years (Earthtrust 2001, animalinfo 2001, Monachus 2001), the dose is probably overestimated by another factor of two. Using all these conservative assumptions, the annual dose equivalent is calculated to be 0.03 Sv/year (30 mSv/year). By comparison, the IAEA recommended limit for reproductive effects in animals is 0.365 Gy/year (36.5 cGy/year) (Linsley 1997). The annual dose equivalent calculation used human quality factors to convert the dose rate to a dose equivalent rate. The IAEA recommended limit is for gamma exposure; by applying the human quality factor (1 for gamma rays) to the recommended dose limit (to convert gray to sievert), the IAEA dose equivalent limit would be 0.365 Sv/year (365 mSv/year), ten times higher than the value calculated for the Hawaiian monk seal.

The dose calculation assumed the Hawaiian monk seal lived in the JA area all year and ate only the highest average Pu-concentrated fish throughout the year for its entire life, which contradicts the seals' actual habits and life cycle. Considering the seals' actual diet, movement and feeding habits, and their current occupancy rates around JA, achieving even 10% of the IAEA annual limit is impossible. Chronic exposure to radiation usually does not manifest into a health risk until after 20 years and the chronic mortality limit recommended by the IAEA is ten times higher than the reproductive limit, this adds additional conservative aspects to the seal's dose calculation. The actual risk associated with the dose could be hundreds, even a thousand times less depending on how much fish is actually consumed and how often the eaten fish were surgeonfish from offshore of the RCA in addition to the other conservative estimates discussed above.

Annex J RESPONSES TO PUBLIC COMMENTS FROM MAY 2001 MEETINGS

The Defense Threat Reduction Agency (DTRA) has prepared a corrective measures study/feasibility study (CMS/FS) to evaluate several alternatives for the disposition of radioactive coral, metal and concrete debris located on Johnston Island (JI), Johnston Atoll (JA). From May 21-24, 2001, DTRA conducted a series of public availability sessions and a public meeting at several locations in the state of Hawaii. The combined purpose of these events was to present a status report on DTRA's plutonium cleanup project at JA, to solicit public comment on those draft alternatives, and to seek input on other possible approaches. As a result of this public scoping process, seven separate submissions, each containing a number of comments, were received by June 15, 2001, the end of the public comment period. Two attendees at the public availability sessions made videotaped statements for the record.

Comment: One commenter suggested the formation of a National Plutonium Cleanup Task Force to address the cleanup of JA.

Response: DTRA, which is responsible for the cleanup of the radioactive contamination, has involved regulatory and other government agencies in this project including the U.S. Environmental Protection Agency (EPA), the U.S. Fish and Wildlife Service (USFWS), and the U.S. Air Force. Scientists from Boston University, Oregon State University, and Oak Ridge National Laboratory (ORNL), in particular, have also been involved. DTRA has also sought public input throughout the project's decision-making process. This project is being conducted in accordance with applicable established regulations and procedures (see comment below and the CMS/FS introduction for the applicable regulations), and all appropriate agencies and the public will have ample opportunity to review the documents. Additional review by such a task force would only result in an additional delay.

Comment: Several commenters questioned why this effort was not being conducted under the National Environmental Policy Act (NEPA).

Response: This effort was conducted under the Defense Environmental Restoration Program (DERP), a program formally established by statute that provides for the cleanup of hazardous substances associated with past Department of Defense (DoD) activities consistent with the provisions of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), which covers Atomic Energy Act materials. The overall NEPA mandate for a fully-informed and well-considered decision will be achieved through adherence to the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), which implements CERCLA, and through adherence to the DERP statute. The NCP requires, among other things, public involvement, consideration of environmental effects, and selection of a remedial action that meets legally applicable standards under Federal or state law (including the Endangered Species Act), which are also NEPA's substantive requirements. The document DTRA has prepared, the CMS/FS, is equivalent in detail and comprehensiveness to an environmental impact statement prepared under NEPA, and the process is analogous to the NEPA process. The Department of Justice and the courts have upheld CERCLA's functional equivalency to NEPA.

Comment: Several commenters stated that the public sessions were not advertised widely enough or far enough in advance.

Response: Paid advertisements appeared in both statewide newspapers as well in as the three neighbor island newspapers, exceeding the statutory requirements of CERCLA. Notices also appeared in the statewide environmental publications, the *Midweek* and *The Environmental Notice*. Interviews of DTRA personnel appeared in two of the newspapers before the meetings; both articles contained the meeting schedule. All major television and radio stations were notified and were reminded the week before the public sessions began. In all, 19 print news media outlets, 27 radio stations, and eight television stations were provided news releases via facsimile; receipt was confirmed by telephone. Public libraries throughout the state were sent copies of the notice for their public display areas in accordance with advice provided by the Hawaii State Public Library System. DTRA also posted this information on its website. More than 80 individual notices were sent to interested parties and environmental organizations, including those who attended the previous public meeting on July 12, 2000. A media availability day was held in Honolulu on May 18, 2001. However, DTRA appreciates the efforts by some attendees to pass along the meeting information to other interested parties who may not have seen the public notices.

Comment: Two commenters suggested holding public meetings at other locations around the United States.

Response: It is DoD policy to involve the local community throughout the environmental restoration process. Unlike most military installations, which have local communities adjacent to the installation, the nearest community to JA is 800 miles away, in Hawaii. Therefore, DTRA selected Hawaii as the location in which to hold public meetings. Holding additional meetings at other U.S. locations would increase project costs and would not involve U.S. populations that are closer to the atoll.

Comment: One commenter stated that the public comment period was very short.

Response: The comment period for the draft alternatives and other possible approaches began on May 7, 2001, and ended on June 15, 2001. In advance of this, information was distributed to various public libraries in Hawaii and to involved organizations and citizens who had previously expressed interest in the project. Our intent was to provide a status report on the project and solicit public input on the various alternatives for the disposition of the coral, metal and concrete debris. DTRA believes that 40 days was sufficient because there was no significant document to review during this scoping stage. The total amount of time for public comment for this project to date has been 120 days (80 days in 2000 for the highly technical risk assessment and proposed cleanup level, and 40 days for the scoping effort in 2001). For the draft final CMS/FS, DTRA has planned a public comment period from March 1 through April 19, 2002, with public meetings scheduled on March 13, 15, 18, and 20.

Comment: One commenter suggested that the structure of the public meeting was flawed.

Response: The purpose of the scoping meeting was to provide a status report on the plutonium cleanup project at JA, introduce the various alternatives under consideration and solicit public input for the disposition of the coral, metal and concrete debris.

Comment: Commenters submitted two additional alternatives. One, to cover JA with a 24-inch-thick concrete cap and an additional impervious membrane, would destroy all bird nesting habitat.

The second alternative, phytoremediation, has a number of drawbacks. Research has shown that, while some plutonium is incorporated into plant tissues, the concentrations are typically orders of magnitude less than found in soils and sediments. Plutonium oxide (PuO_2) is not soluble in water and not bioavailable. Phytoremediation has been shown to work for uniformly distributed contaminants, but the PuO_2 at JA is localized and very particularized, further reducing the possible effectiveness of phytoremediation efforts.

There are other concerns with phytoremediation. The first is whether non-native plants (such as corn, wheat, and soybeans) can survive and grow in the calcium carbonate (coralline) matrix at JA. If they cannot, then soil amendments and fertilizer would have to be imported and mixed with the on-site soil, adding to the volume of PuO_2-containing material. The USFWS would likely object to the introduction of non-native species for this purpose. The proposal also appears to be labor intensive. JA is being closed as a military installation; the USFWS, which now manages and will continue to manage the JA National Wildlife Refuge (JANWR), plans to have a only a small research team on the atoll for relatively short periods of time. After each growing season, replanting would be necessary, since the plants would have to be harvested to remove the PuO_2. This effort would require annual labor and logistical support. Annual plowing, harrowing, and planting would destroy nesting habitat. There also remains the question of what to do with the plants if such an effort were successful—the PuO_2 would still exist in the harvested plants.

The climate at JA is subhumid, with an average annual precipitation of 26 inches. Annual precipitation is extremely variable because major rainfalls are associated with sporadic storms, and the evaporation rate is high. There are no natural, permanent bodies of fresh water on JA. Due to the high permeability of the soil, the unavailability of fresh water would limit the effectiveness of any phytoremediation effort. There would be no way to produce sufficient fresh water with the projected infrastructure once the DoD leaves JA. DTRA will revegetate the cap for the landfill alternatives with native plants likely to survive on JA for erosion control and bird habitat improvement in cooperation with the USFWS, but it does not plan to conduct phytoremediation research.

Comment: One commenter wanted to know if "hot spots" of radiological contamination in the “above” pile could be identified.

Response: The coral was separated by the Segmented Gate System (SGS) according to its radiological contamination. Coral above 13.5 pCi/g was placed in the “above” pile. Further separation of the "above" pile by the SGS is impractical since the cleanup level was established at 13.5 pCi/g, the original target level for separation. DTRA approached private industry in 1997 to seek alternative methods to separate PuO_2 from coral. Although some methods showed some early promise, none were effective or practical for the volume of the “above” pile.

Comment: One commenter raised a concern about the possibility of plutonium leaching into the groundwater over the years.

Response: The solubility and column leachate tests conducted by ORNL showed that plutonium oxides do not significantly move into solution at JA. PuO_2 is essentially insoluble in water, and especially so in the carbonate environment at JA. A sampling program showed that the level of radioactivity in the brackish water lens that serves as the source for drinking water on JI is 1% of the EPA's drinking water standard for radionuclides. This is less than one would see from natural radioactivity as water percolates through uranium-bearing rocks and soil. Furthermore, the groundwater is not potable without treatment, and no future use of the groundwater as a water supply is anticipated.

Comment: One commenter stated that DTRA was limiting discussion to only the alternatives presented.

Response: One of the stated purposes of this public scoping effort was to solicit public input to determine whether DTRA had overlooked one or more alternatives or some recently developed and applicable technology. Two additional alternatives were proposed in writing during the public comment period (see discussion above).

Comment: One commenter favored the alternative of a landfill with a concrete cap, but suggested not revegetating the final cap at all, as that would likely attract wildlife.

Response: Revegetation will inhibit erosion and may provide additional habitat for nesting and roosting birds. DTRA has demonstrated that it is extremely unlikely that either resident or migratory shorebirds or seabirds would receive doses in excess of recommended limits (DNA 1991). Since the atoll is a National Wildlife Refuge, the creation or improvement of habitat is a goal of the remediation process.

Comment: A commenter suggested covering the atoll with a layer of salt to "help mitigate the radiation" and prevent wind-blown redistribution of the residual surface contamination.

Response: Presumably, the thought is that the salt would form a protective crust, preventing transport by wind. A layer of salt, which is water-soluble, would have adverse impacts on wildlife and vegetation and would not reduce the already low risk from radioactivity (see CMS/FS section 3.3).

Comment: Another commenter suggested that any alternative selected should leave open the possibility of removing the radioactively contaminated material at a later date if technology is developed to further reduce the volume or level of radioactivity.

Response: The alternative selected does not preclude such an outcome, although removal of the 2-foot-thick coral cap would require the importation and use of heavy equipment. The vitrification and concrete slurry alternatives would complicate any future removal.

Comment: One commenter inquired as to the rationale behind a 2-foot thick cap of coral from the “below” pile.

Response: The reason for that particular thickness is that DTRA has been advised by a JANWR manager that the birds on JA that burrow in the surface generally do not burrow below a depth of 61 cm (2 feet).

Comment: One commenter inquired as to when the results of the various field investigations would be made available to the public for review.

Response: They are available as appendices to the CMS/FS.

Comment: Two commenters stated that plutonium is the most toxic (or hazardous) substance known to man.

Response: This claim is without basis in science and has been discredited thoroughly in the technical literature. While plutonium is toxic, it is by no means the most toxic substance known.

Comment: A commenter stated that "inhalation of even one tiny speck of plutonium dust is enough to cause death."

Response: This is known as the "hot particle" theory, and it has been studied at length and rejected by the U.S. Atomic Energy Commission (now the U.S. Department of Energy (DOE)), the U.S. Nuclear Regulatory Commission (NRC), a committee of the U.S. National Academy of Sciences, the U.S. National Council of Radiation Protection and Measurement, and the British Medical Research Council, among other groups (see CMS/FS section 4.3).

Comment: Two commenters asked DTRA to consider the effects of global warming and rising sea levels on JA.

Response: Increased erosion would be a likely consequence of relative sea-level rise (whatever the cause) at JA, particularly along the south shore, which is already the most vulnerable to erosion by wave action, as discussed in the CMS/FS (section 9). The maximum elevation on JA is about 5 m (16 feet) above sea level, with the average elevation approximately 2 m (7 feet). The CMS/FS (section 9) addresses the scenario of complete submergence because of erosion and seawall failure.

Comment: Several commenters were concerned about the level and distribution of radioactivity below the surface layer and whether DTRA planned to survey the subsurface.

Response: Statistically, DTRA expects the distribution of radioactivity at depth in these portions of the island to be the same as at the surface, considering how the islands were expanded and the characteristics of the contaminants. Over the years, the islands have been reworked significantly for construction of facilities. Radiological surveys were conducted for every excavation, no matter how minor, and after hurricanes, and all "hot spots" were removed and placed in the Radiological Control Area (RCA) for further action. Almost all of the buildings and facilities date from the mid-1960s, and some of those excavations were substantial, such as those for the foundations for large buildings. The physics of radiation (alpha particles and low-energy gamma rays) and the shielding effects of the coralline soil prevent subsurface viewing. The estimated concentration of the subsurface is 2.57 pCi/g. A complete survey of the subsurface would require progressive removal of soil layers, with each new surface scanned sequentially, until the original 1962 ground level was reached, much like peeling an onion. This approach would result in the destruction of dozens of acres of existing and potential bird habitat. A surface cleanup level of 13.5 pCi/g is very protective of human health and wildlife. The RCA itself has been excavated to well below grade and was resurveyed in 1999. Land-use controls (LUCs) and limitations for use when this project is completed can be found in the CMS/FS (section 5.3).

Comment: Several commenters asked about the radiological surveys completed at JA.

Response: The radiological surveys conducted on the RCA, the Outer Islands, and JI were conducted according to the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM). The manual is a multi-agency consensus document developed by the DoD, the DOE, the EPA, and the NRC. The manual lays out specific planning steps, equipment requirements, and quality assurance procedures. DTRA followed the guidance from the manual when conducting the surveys. The areas covered by buildings, concrete, the runway and taxiway, or heavy brush are not accessible. It is a physical impossibility to "see" any plutonium underneath these surfaces. It is reasonable to say that the areas covered are not significantly different than the exposed areas. All accessible areas have been surveyed, and the survey results are part of the CMS/FS (section 2.3). The entire accessible (undeveloped) land surface surveyed outside of the RCA is approximately 14 million square feet or 320 acres. The developed areas were surveyed at the time of facility construction, and "hot spots," if any, were removed at that time. For the recent radiological survey, detected "hot spots" were removed to the radiological material storage bunker. Less than 0.5% of the samples exceeded the recommended soil cleanup level. DTRA does not expect the distribution in the developed areas or the distribution below the surface to be different from what was observed in the surveyed areas. DTRA does not plan to perform additional surveys.

Comment: Several commenters suggested DTRA remove contamination from the lagoon in an "environmentally friendly" way.

Response: Several years ago, DTRA developed a prototype underwater radiation detector to conduct surveys in the lagoon at JA. It was labor intensive, cumbersome, and unreliable. Since the material is covered by sediments in the lagoon or encased in the nonliving coral skeletons, it is better left where it lies. Investigations conducted since the 1960s have detected no adverse effect on the marine life. Under water is an acceptable place for materials that emit alpha particles, whose range is greatly reduced from that in air. Sediments have built up, covering the material and reducing its exposure to plants and marine life. Even if DTRA were able to easily detect locations of radioactive material and attempt to remove it from the lagoon, it would do more harm than good to dredge it up, thereby creating other problems in the lagoon (as a result of the effects of increased turbidity) and damaging coral heads. There is no way to remove the material with surgical precision. Even if DTRA removed as much as 95% of the material, much of what would remain would settle on the surface. Dredging would reverse nature's healing process, damage the reef, and be prohibitively expensive. Dredging would also expose the submerged PuO_2 to the air, making it a possible inhalation hazard to humans. A recent lagoon sediment sampling program revealed that of 113 cores, only 5 had values greater than the cleanup level of 13.5 pCi/g, and all were in the area immediately offshore of the RCA . Only 1 of those 5 samples was at the surface, and the others were at depths greater than 3 inches. The preponderance of the radioactive material was found at depths from 6-12 inches below the sediment surface.

Comment: Three commenters were concerned about plutonium in the Pacific Ocean outside the atoll.

Response: Any material outside the atoll platform is considered unreachable because the ocean floor drops precipitously beyond the coral reef. During the initial cleanup efforts in 1962, material was packed in containerized express boxes and disposed of approximately 8 miles outside the reef at a depth of about 6,000 feet. Review of the available records found only brief descriptions of the disposed material. Measurements at the site have shown that the concentrations of radioactive material are not distinguishable from global fallout levels common at the depths sampled in this region of the Pacific Ocean.

Comment: Two commenters raised the issue of radioactive fallout.

Response: This project is limited to the cleanup of PuO_2 from the oxidation of weapons-grade plutonium that was distributed across JA as a result of two aborted missile launches in 1962. This is unrelated to the widespread radioactive fallout from other atmospheric nuclear tests.

Comment: Two commenters preferred the vitrification alternative or some variation with additional engineered features, such as placing the vitrified material in a concrete vault with an impervious liner.

Response: The vitrification alternative was not selected for reasons explained in the CMS/FS (section 8). Additional engineered features would not provide measurably greater protection from radioactivity or erosion, and the added expense would not be commensurate with the insignificant reduction in the already negligible risk. The RCA, where a landfill would be constructed, is located in the area of JA that is already the least vulnerable to erosion by wave action; placing the vitrified material elsewhere would eliminate that advantage.

Comment: Several commenters proposed that DTRA conduct more research on the effects of radioactivity on birds, seals, fish, coral, crustaceans, eels, mollusks, shellfish, and insects before proceeding with its restoration efforts. In support of this suggestion, one commenter cited "reported fin deformities" in reef fish.

Response: There is no evidence of any effects of radioactivity on human health or any species of wildlife at any stage of their development or life cycle at JA. After consultation with the EPA, the USFWS, and Boston University marine scientists, it was agreed that the best species to be sampled for plutonium uptake were the bottom-feeding surgeonfish and the goatfish.

DTRA and Boston University marine scientists collected fish both with and without fin deformities and had them analyzed by ORNL. There was no statistical difference in plutonium concentration between the normal fish and those with fin deformities. This is addressed in detail in the CMS/FS (annex I section 3-1). Abnormalities occur with some frequency in nature, and observed abnormalities at JA have always been within the range of natural variation and have not been attributed to any particular contaminant or combination of contaminants. Because these species have a short natural life, there is less chance of a chronic effect from the radioactivity.

Comment: One commenter specifically asked why DTRA did not sample the parrotfish, which grazes on coral polyps.

Response: The parrotfish would not be a species likely to have plutonium uptake. Because there is no evidence of radioactivity in the water column, and PuO_2 is not soluble in the environment at JA, it is unlikely that the coral polyps, on which the parrotfish feed, would contain plutonium. The only place PuO_2 is likely to be found in the nonliving calcium carbonate skeletal structure is in the growth dating from 1962, not in more recent growth or in the actively growing coral. The fish selection criteria are discussed further in the CMS/FS (annex I, section 3).

DTRA's risk assessment demonstrated that it was extremely unlikely that either resident or migratory birds would receive doses in excess of recommended limits because of limited exposure pathways, low bioaccumulation factors, and low radiation dose factors from the soils. The cleanup level of 13.5 pCi/g is well below international standards for the protection of human health and wildlife, and far below levels at which effects would be observed. The EPA has established that a standard at a level designed to protect human health also protects many ecological receptors. However, the prediction of ecological effects at contaminated sites is problematic because the radiation dose-response relationships are not well understood. The responses of aquatic populations to chronic radiation exposure are difficult to document and quantify and will vary with life stage. As for acute exposures, very low doses (i.e., 1% of the lethal dose) are not likely to produce measurable perturbations in populations or communities. From a review of extant literature, the EPA concluded that:

Invertebrates (including insects), non-vascular plants, and reptiles and amphibians are highly resistant to radiation effects compared to mammals such as humans;

Several species of large mammals appear to be equally sensitive as humans to acute radiation exposure;

Certain pines and some wild birds are as radiosensitive as many mammals following chronic radiation exposures;

Birds are generally less radiosensitive than most mammals; and
Aquatic vertebrates are more radiosensitive than invertebrates and exhibit sensitivities similar to that of terrestrial mammals.

Although reproductive and early developmental stages in aquatic organisms are most sensitive to chronic radiation, studies at JA over the years have shown no adverse impacts from radioactivity to the marine life since the aborted launches. One of the country's leading ornithologists, who has studied the birds at JA since 1983, has stated that there are no documented effects on tropicbirds and other species on JA from contaminants, including radioactivity. There is no area on JA that has reduced hatching success of eggs or fledging success of chicks. None of the seabirds picks up food on land to eat, so they would not pick up contaminated soil. No data indicate that seabirds are ingesting any contaminants that affect their reproductive success and survival. None of the nesting species at JA generally feed in the lagoon, but rather in the open ocean. Therefore, no lagoon contaminants are likely to be reflected in the birds, because their diet is primarily flying fish and squid, which are pelagic species, not bottom-feeders. Based on DTRA's investigations of the fish in the lagoon, the risks to human health (from consumption of lagoon fish) and to wildlife at JA are so low they do not warrant further investigation.

DTRA's recent investigations of the ecological effects of radioactivity at JA demonstrate that the birds, fish, and green sea turtles would receive well under 1% of the International Atomic Energy Agency (IAEA) dose limits established for those organisms. Furthermore, the natural resources have been studied extensively since the early 1980s when planning began for the Johnston Atoll Chemical Agent Disposal System (JACADS). Ecological surveys date back to 1923. Scientists from the University of Hawaii, Woods Hole Oceanographic Institution, Boston University Marine Program, Oregon State University, the Smithsonian Institution, and the DOE National Laboratories, among others, have conducted numerous surveys and research activities at JA, including radiological research sponsored by DTRA. From all indications, the marine and bird populations at JA are thriving. There is no evidence of any effects of radioactivity on human health or any species of wildlife at any stage of their development or life cycle at JA. DTRA has demonstrated that this is due to limited exposure pathways, low bioaccumulation factors, insolubility of PuO_2 in the environment, and low radiation dose factors from the soils and sediments.

Even assuming that the Hawaiian monk seal resides at JA year-round, eats 3,000 grams of only bottom-feeding fish per day, and feeds exclusively in the area of the lagoon immediately offshore of the RCA, calculations indicate that the dose to the 400- to 600-pound monk seal would be about 10% of the annual limit set by the IAEA. These assumptions are very conservative; that is, they represent a worst-case scenario that is highly improbable. Bottom-feeding fish in the area weigh on the order of 100 grams each, so an intake of 30 fish per day per seal would quickly lead the seals to expand their feeding area. Furthermore, the Hawaiian monk seal is a rarity at JA. The National Marine Fisheries Service recently evaluated data on the range of the Hawaiian monk seal and concluded that JA is "probably at or near the range boundary," and that "development of a seal subpopulation is hindered by the long distance from a source of immigrants and by a limited amount of undisturbed beach area on which the seals could rest" (NOAA 2001).

Comment: Two commenters expressed concern that use of the “below” pile of coral as the final cap for the landfill alternatives would result in wind-blown redistribution of the radioactivity.

Response: DTRA thinks that is a highly improbable scenario. Years of air measurements immediately downwind of the RCA indicate that the maximum air concentrations of plutonium reached only 1% of the NRC’s workplace standard and remained below the limit for the general public (10CFR20, Appendix B) for plutonium. Those maximum concentrations were achieved during heavy equipment operations (bulldozing, excavating, and rock crushing) that would generate dust. DTRA has no reason to think that landfill construction would result in higher concentrations. Each layer or lift would be wetted down during placement to further reduce the possibility of airborne contaminants. The “below” pile of coral meets the same cleanup standard as the soil covering the remainder of the atoll, which is deemed suitable for unrestricted use, including airfield and refueling operations. Considering those results and the crushed and compacted coral's cementitious nature, it is unlikely that measurable wind-blown redistribution would result from the coral from the “below” pile after placement as a cap over one of the landfill alternatives. DTRA would expect similar results when the “above” pile is moved and placed in the excavation.

Comment: Two commenters asked about the metal and concrete debris.

Response: The metal debris and concrete debris have only surface contamination. Since 1962, the concrete has been broken into more manageable pieces, exposing surfaces that were protected from the original contamination. Today, there is a larger exposed surface area than in 1962. Additionally, the debris has been exposed to the weather since 1962, possibly reducing the surface contamination. If the concrete were to be used for rip-rap or artificial reef building, the concrete would have to be reduced further in size for manageability and then radiologically surveyed for release at 16.8 pCi/cm^2. The concrete that passed the survey (below that level) could be taken out of the RCA for use. Concrete that failed the survey or was not reducible to manageable sizes would remain in the RCA for other action. Shipping the concrete off-island would require it to be reduced to manageable sizes, and a complete radiological characterization would have been required. The level of the characterization would be determined by the final destination; it would include, at a minimum, surface scans and swipe tests.

The metal debris is coated with rust and would be impossible to survey; as a result, this limits the alternative for the metal debris to landfilling. The unrestricted release standard, as stated in American National Standards Institute N13.12 (1987), is 20 disintegrations per minute/100cm^2 (dpm/100cm^2)(removable) and 200 dpm/100cm^2 (total). Any scrap metal dealer willing to accept the metal would determine the actual standards. An additional concern is the uncertainty of the final use of the recycled metal. The landfill alternative for the concrete and metal does not require a survey because the debris would not leave the RCA.

Comment: Several commenters raised, either directly or indirectly, the issue of land-use restrictions or prohibitions, particularly if JA becomes a refueling point for aircraft and there is a need to excavate trenches for pipes. DTRA has developed draft LUCs as part of the CMS/FS (section 5.3).

Response: With proper LUCs, it will not be necessary, as one commenter suggested, to prohibit all human activities except for research activity and monitoring. Nor will it be necessary to prohibit any future activity that could disturb the subsurface area for a distance of 100 yards around the site of the landfill. Excavation will be prohibited in the RCA. Enforcement of the LUCs will be the responsibility of the USFWS. Some of these LUCs will not be finalized or refined until DoD transfers JA completely to the USFWS, particularly if the USFWS modifies its plans for the JANWR. The draft LUCs are more than adequate to limit additional risks to human health and birds given the current land-use plans for the JANWR.

Comment: Several commenters expressed concern that natural processes, such as hurricanes, or human activity could expose PuO_2 at levels higher than the cleanup standard of 13.5 pCi/g.

Response: If such exposures are detected, DTRA will have the "hot spots" shipped off-island to a permitted radioactive waste facility. However, there is no evidence—observed, detected, or anecdotal—of any effects of radioactivity on human health or any species of wildlife at any stage of their development or life cycle at JA at any time since the aborted launches. A LUC will be developed to cover the possibility that "hot spots" may be exposed in the future.

DTRA plans to monitor the landfill site for construction and cap integrity annually for a period of 5 years or until routine, scheduled airline service to JA is terminated, whichever comes first, to determine whether any problems have arisen in the event of improper construction. If any radioactive contamination above 13.5 pCi/g is found after landfill monitoring is completed, the contamination will be evaluated by DTRA health physics staff. The DoD does not plan to monitor or maintain any portion of the seawall. Without periodic maintenance and repair, the seawall will fail; a rough estimate of seawall duration in its current state is between 30-50 years. There is no way to predict what section of the seawall will fail first or what the ultimate sequence of events will be. However, the portion of the seawall that is closest to the RCA is subject to less wave action than anywhere else on JI and is perhaps the least likely to fail within that period.